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JADS JT&E

System Integration Test Linked Simulators Phase Final Report

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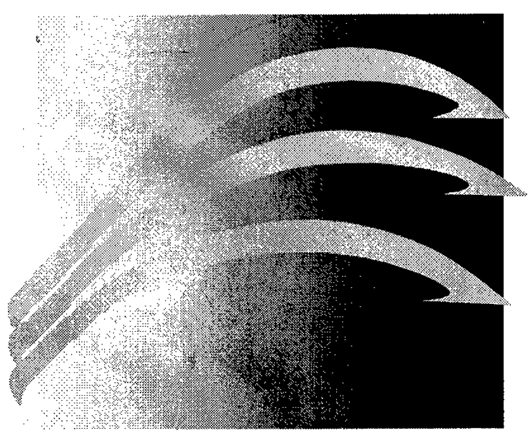

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EXECUTIVE SUMMARY

1.0 Introduction

This summary is designed to serve as a stand-alone document as well as part of this report. For that reason, the reader will find some duplication of verbiage and figures between the summary and the full report. The Naval Air Warfare Center Weapons Division (NAWCWPNS) was a committed and effective partner for the Joint Advanced Distributed Simulation Joint Test and Evaluation (JADS JT&E) Joint Test Force (JTF) in the planning, preparation, and execution of the Linked Simulators Phase (LSP) of the System Integration Test (SIT).

2.0 JADS Overview

The JADS JT&E was chartered by the Deputy Director, Test, Systems Engineering and Evaluation (Test and Evaluation), Office of the Under Secretary of Defense (Acquisition and Technology) in October 1994 to investigate the utility of Advanced Distributed Simulation (ADS) technologies for support of Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). The program is Air Force led, with Army and Navy participation. The JTF manning includes 23 Air Force, 13 Army, and 2 Navy. Science Applications International Corporation and Georgia Tech Research Institute provide contracted technical support. The program is nominally scheduled for five years.

The JADS JT&E is directly investigating ADS applications in three slices of the T&E spectrum: a System Integration Test (SIT) which explores ADS support of air-to-air missile testing, an End-To-End (ETE) test which explores ADS support for Command, Control, Communications, Computers, and Intelligence (C4I) testing, and an Electronic Warfare (EW) test which explores ADS support for EW testing. The JTF is also chartered to observe, or participate at a modest level, in ADS activities sponsored and conducted by other agencies in an effort to broaden conclusions developed in the three dedicated test areas.

Phase 1, the Linked Simulators Phase (LSP), of the SIT is the subject of this summary report.

3.0 SIT Overview

The SIT is a two phase test designed to examine the application of ADS technology in two architectures. The first phase employed an all simulator architecture which incorporated a manned F-18 avionics lab (simulator) at China Lake NAS as a shooter, a manned F-14 avionics lab (simulator) at Point Mugu as a target, and a missile hardware-in-the-loop (HWIL) simulation lab (SIMLAB) at China Lake which generated AIM-9 missile flyouts and injected countermeasures (flares). The second phase of the SIT employs an architecture which incorporates a live F-16 shooter aircraft, a live F-16 target aircraft, and an Advanced Medium Range Air-to-Air Missile (AMRAAM) HWIL simulation hosted in the Eglin AFB Guided Weapons Evaluation Facility (GWEF). This document summarizes the LSP activities.

4.0 LSP Test Plan Overview

4.1 Purpose

The LSP was designed to examine the real-time interactions between networked manned flight simulators, a missile HWIL simulation facility, and a control center. The focus of the examination was on the relationships between network performance, system under test (SUT) data, and test measures of interest. In general terms, the purpose was to collect data on the quality and usability of test data in this particular distributed test architecture. The test objectives were:

4.1.1 Objective 1: Assess the validity of AIM-9 data obtained in the LSP ADS configuration
4.1.2 Objective 2: Assess utility of LSP ADS configuration for parametric studies
4.1.3 Objective 3: Assess effect of latency on validity of test results
4.1.4 Objective 4: Assess ability of LSP ADS configuration to support AIM-9 testing (This test objective was broken into subobjectives as follows.)

- 4.1.4.1 Subobjective 4-1: Assess capability of network to provide required bandwidth and connectivity
- 4.1.4.2 Subobjective 4-2: Assess the effects of ADS-induced errors on LSP test results validity
- 4.1.4.3 Subobjective 4-3: Assess adequacy of standard data protocols for LSP test
- 4.1.4.4 Subobjective 4-4: Assess reliability, availability, and maintainability of ADS network
- 4.1.4.5 Subobjective 4-5: Assess capability for centralized test control and monitoring

4.2 Approach

The F/A-18 Weapon System Support Facility (WSSF) at China Lake and the F-14D Weapon System Integration Center (WSIC) at Point Mugu were the shooter and target, respectively. The shooter "fired" the AIM-9 in the SIMLAB at the target which could respond with countermeasures. Runs were controlled from a test control center which ensured all nodes were ready for each run, issued start/stop directions, and processed data packets for real time analysis of system performance. Test control was exercised from the Battle Management Interoperability Center (BMIC) at Point Mugu while the JADS Joint Test Force was physically relocating. Control switched to the JADS Test Control and Analysis Center (TCAC) after their move was complete.

Information was exchanged between participants in the form of Distributed Interactive Simulation (DIS) Protocol Data Units (PDUs). Entity state data (positions, velocities, accelerations, attitudes, attitude rates) at the output node were converted from simulator format to PDUs, and reconverted at the receiving end, into simulator format. An exception was the link between the Stores Management System of the shooter, and the missile in the SIMLAB which used 1553 data bus format. The architecture is shown below.

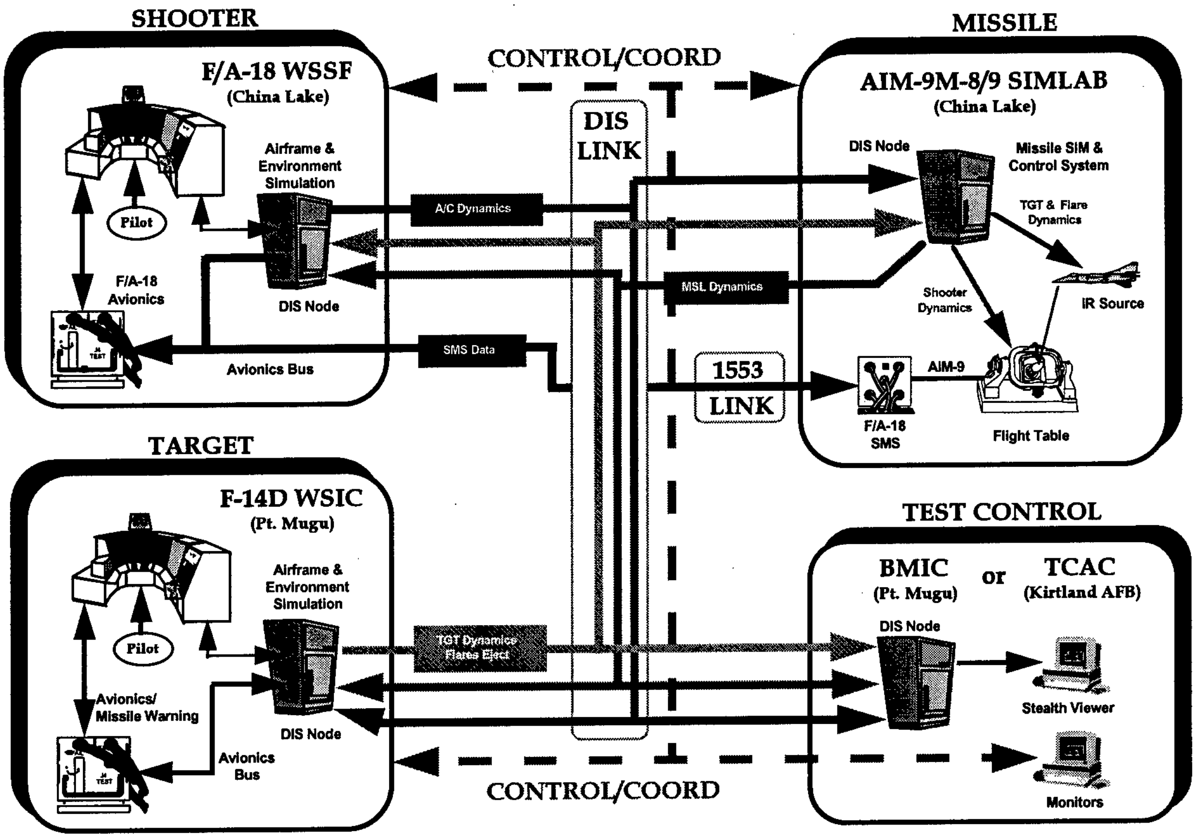

Figure ES-1. Linked Simulators Phase Test Configuration

A baseline engagement profile (LPN-15) was selected from the AIM-9M-8/9 Joint Initial Operational Test and Evaluation (JIOT&E) test series (conducted 17 May 1993 to 29 October 1993).

This single engagement geometry was the basis for all trials in the LSP. The selection of this baseline from the 16 live fire profiles of the AIM-9M-8/9 JIOT&E was based on three factors: (1) the shooter was an F/A-18, (2) flares were deployed, and (3) sufficient live fire data were available for V&V of the LSP trials. Additional details on LPN-15 are in Appendix A. The profile is depicted in Figure ES-2.

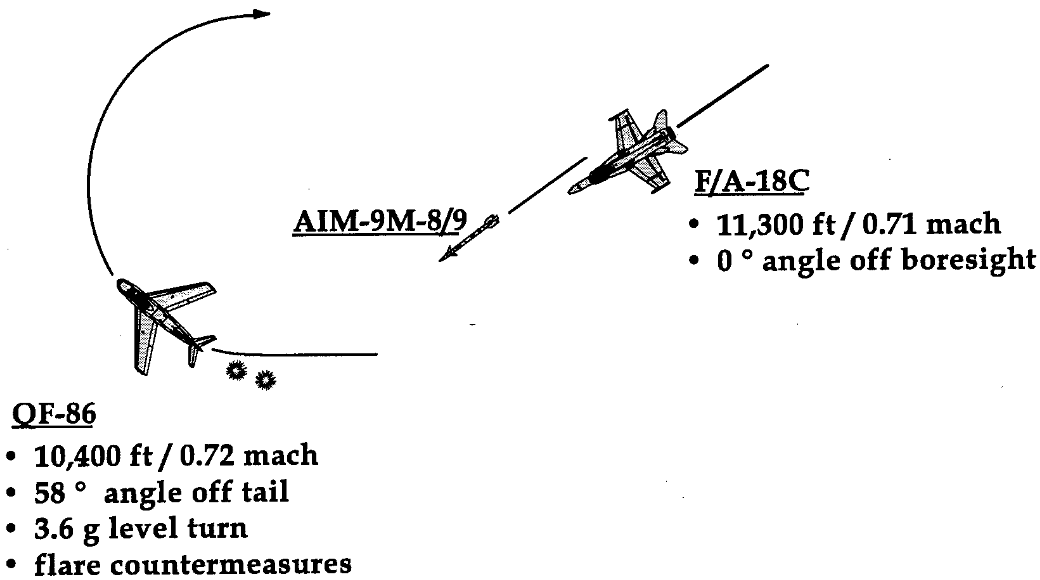

Figure ES-2. Live Fire Profile (LPN-15, 9 June 93)

The test plan scheduled three blocks of simulation "missions" as shown in Figure ES-3. The first to do Verification and Validation (V&V), the second to do parametric studies, and the third to study latency.

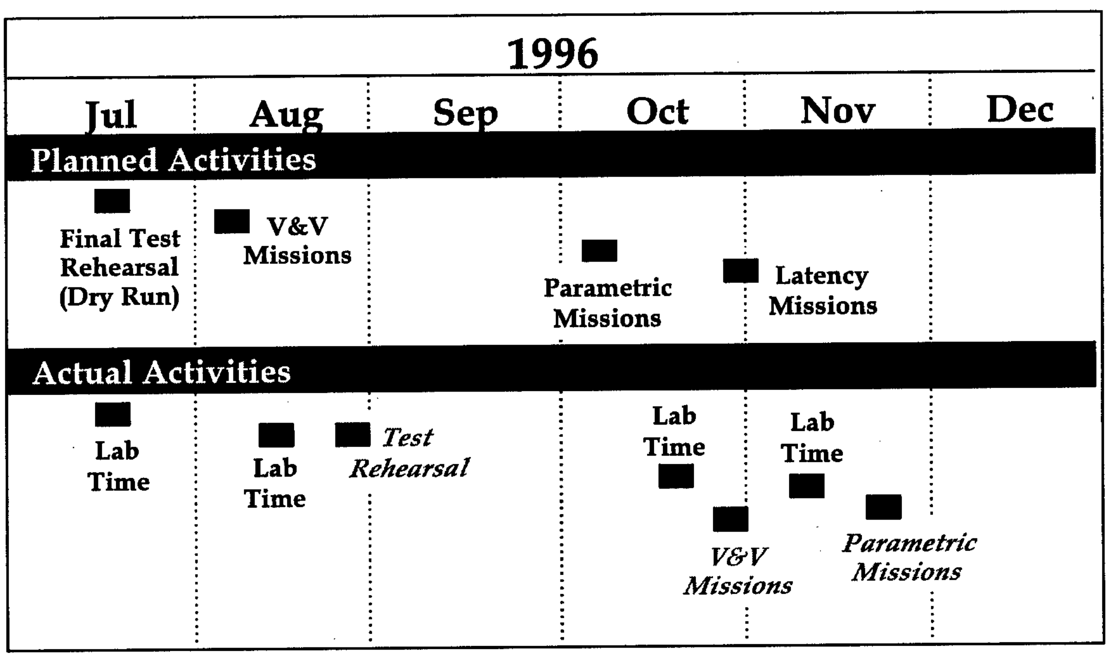

Figure ES-3. Linked Simulators Phase Test Schedule

The planned schedule is shown on the upper half of the Figure ES-3.

4.3 Instrumentation

One of the major distinguishing characteristics of a distributed testing architecture, as opposed to a distributed training architecture, is in the degree of instrumentation. The LSP architecture was instrumented to a level which supported the measurement of latency values, synchronization differences, position transformation errors, missile seeker performance, and the whole gamut of network performance measures.

5.0 LSP Test Results

5.1 Schedule

If the reader will refer to the bottom half of Figure ES-3, he will find the time lines for actual testing. The time required to integrate and check out the architecture was significantly longer than planned. Full-up architecture configurations were required to verify fixes to integration problems. (Stand-alone fixes were postulated, and tried, but most fell short when the network was reinitiated.) The periods of integrated verification work were called "lab periods", and they moved scheduled test activity to the right on the timeline. In fact, there were still some problems at the start of execution of the V&V missions, and one could argue that we weren't really ready to test until the Nov test. The 3 to 4 month slip was a reflection of number of things:

1. This technology is definitely not "plug-and-play" in T&E applications.
2. There is a significant learning curve for people inexperienced in establishing these architectures.
3. The learning curve applies at every node of a distributed architecture.
4. System integration is the name of the game.

If the same team of people were to construct a similar architecture now, set-up and check out would probably take a small fraction of the time experienced on this first test sequence.

5.2 V&V Missions

The underlying assumption in the approach to V&V was that JADS would quantitatively compare the representation of participant and SUT behavior in the LSP architecture with the results of the live test. The statistical reality was that we only had a single data point on the live side of the comparison, and a rigorous quantified approach was not practical. The test force fell back upon a qualitative comparison of live profiles with the ADS profiles, and found that comparison useful.

5.3 Parametric Missions

The expectation for the parametric studies was that a selected set of "best" runs, recorded during ADS testing, would be replayed in an automatic mode while selected parameters were varied in a controlled fashion. In fact, since the aircraft simulators were designed to operate with a human at the controls, there was no way to implement automatic runs. The extensive parametric activity planned for was scaled back. However, the pilots were able to achieve reasonably tight adherence

to scripted profiles manually, and the test force concluded that the ADS architecture would be useful for parametric studies.

5.4 Latency Missions

The schedule slippage discussed in Par. 1.4.1 precluded execution of the Latency Study Block of LSP as originally intended. Nonetheless, the JTF collected sufficient data to support a thorough understanding of latency, and its impact on test data in this particular architecture. Latency was addressed in two components, transmission latency, and processing latency. Transmission latency is essentially the time associated with data travel through the WAN legs. That component of latency was predictable and statistically well-behaved. Obviously, transmission latency is a function of distance, but for this test the average latency on the 140 mile leg was about 20 ms. Early on, processing latencies could be as high as several hundred ms. Compared to transmission latencies, processing latencies were not as statistically well-behaved. In the later test events, while it varied from leg to leg, processing latency was about twice the magnitude of the transmission latency component.

5.5 General

5.5.1 Reliability

The reliability of the long-haul elements of the network (the Wide Area Network (WAN) was very good. The availability of the complete LSP ADS configuration was on the order of 85%. Reliability expressed in terms of successfully linked runs was about 67% over the entire span of rehearsal and test activity. Runs failed for a wide variety of reasons involving people, computers, instrumentation, data recording equipment, and simulator performance.

5.5.2 ADS-Induced Errors

ADS-induced errors, aside from latency, were tolerable. Position transform errors were on the order of two to three feet. Initially, there was a significant position divergence problem between the target position as determined by the SIMLAB and the true target location. This was caused by the manner in which the SIMLAB simulation processed the incoming target data for presentation to the seeker and by coordinate transformation inaccuracies. The errors were reduced by nearly an order of magnitude when the transformation was corrected and the PDU update rate increased. The remaining error of about 30 ft is still significant, but the problem appears solvable.

5.5.3 Test Control

Test control procedures were refined throughout the preparation process, and worked well during testing.

5.6 Fulfillment of Test Objectives

All test objectives (See par. 4.1) were met.

6.0 Lessons Learned

6.1 Technical

The test team, and the system experts from each node, need ready access to experts in data transformation and interface software.

Synchronization of activity in a network is difficult. Not every processing element in a distributed architecture has direct access to GPS time, so a "master clock" has to be built into the architecture.

Commonality of ADS hardware and software is necessary. Routers from different vendors may, or may not, interoperate efficiently. Supposedly interoperable software may not work as advertized --- carefully review version numbers.

Understand before designing a distributed architecture what the latency requirements are. Incrementally build to satisfy them.

Special test instrumentation and tools are required to support distributed T&E. The tool set must support rapid identification and characterization of network problems and time tagging of data elements sufficient to support analyses.

6.2 Infrastructure and Process

ADS requirements must be developed early, understood by all parties, and thoroughly documented. The communications required to exercise test control must be identified early.

SUT experts must be involved from the outset.

The architecture build-up must be incremental, beginning with check out of the ADS elements in a stand-alone mode, and evolving, step by step, to the fully integrated configuration.

Problem solving/fixes frequently require verification in a full-up network environment.

Detailed planning for data management is a necessary precursor to testing.

Contracting to support ADS should most often be on a cost plus basis. There are too many unknowns to make fixed price contracting a viable option.

Centralized test control processes have to be integrated with established local processes and procedures.

Configuration control in a distributed architecture is difficult, but essential. The test organization needs to be represented at each test architecture node.

7.0 Conclusions

This particular test architecture would not support valid closed-loop interactions between the missile and target. It could support closed-loop interactions between the shooter and the target for such purposes as test rehearsal. A similar architecture with more representative (realistic) flight simulators could probably support tactics development and training.

With more attention, and more time, better NIUs could have been developed, and better NIUs might improve accuracies and latencies, and ease synchronization difficulties.

Preparation, set up, calibration, and check-out activities are more challenging and time consuming in a distributed environment. The time lines from this particular test, however, should be viewed with caution. The technology's use in T&E is still in its infancy, and the test agencies involved in the integration activities are climbing a steep learning curve. If another tester were to work with China Lake and Pt. Mugu, we believe the preparation time lines would be considerably shorter that they were the first time.

The development of a distributed T&E architecture is not a "plug-and-play" exercise. In the near term, the elements available for linking in a given architecture, were almost certainly not designed to be linked. That means that the burden for making linked architectures work falls upon the interfacing and integrating activities. The NIUs, the translation software, the geographical transforms, etc. are the interface components which allow distributed systems to function with existing players today.

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APPENDICES

1.0 Introduction

1.1 JADS Overview

The Joint Advanced Distributed Simulation Joint Test and Evaluation (JADS JT&E) was chartered by the Deputy Director, Test, Systems Engineering and Evaluation (Test and Evaluation), Office of the Under Secretary of Defense (Acquisition and Technology) in October 1994 to investigate the utility of Advanced Distributed Simulation (ADS) technologies for support of Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). The program is Air Force led, with Army and Navy participation. The Joint Test Force (JTF) manning includes 23 Air Force, 13 Army, and 2 Navy. Science Applications International Corporation and Georgia Tech Research Institute provide contracted technical support. The program is nominally scheduled for five years.

The JADS JT&E is directly investigating ADS applications in three slices of the T&E spectrum: a System Integration Test (SIT) which explores ADS support of air-to-air missile testing, an End-To-End (ETE) test which explores ADS support for Command, Control, Communications, Computers, and Intelligence (C4I) testing, and an Electronic Warfare (EW) test which explores ADS support for EW testing. The JTF is also chartered to observe, or participate at a modest level, in ADS activities sponsored and conducted by other agencies in an effort to broaden conclusions developed in the three dedicated test areas.

The SIT is the subject of this report and is described in the next section; the following is a brief synopsis of the ETE and EW tests.

The ETE will evaluate the utility of ADS to complement the testing of a C4I system. ADS will be used to provide a more robust test environment that provides more representative numbers of threats plus the complementary suite of other C4I and weapon systems with which the system under test would interact. The ETE architecture uses both the Joint STARS aircraft (E-8C) and ground station module; JANUS, a constructive model which generates thousands of virtual targets; and Army command and control (C2) elements. The C2 elements pass aircraft information to a virtual fire direction center, which in turn, directs the fire of a virtual Advanced Tactical Missile System battery against selected targets. The ETE test will execute in four phases. Phase I of the ETE involves testing and verification and validation (V&V) of the simulations in stand alone configurations. Phase II moves from individual aircraft components to an integrated laboratory architecture. Phase III incorporates an E-8C aircraft on the ramp while Phase IV incorporates a flying E-8C.

The EW test, meanwhile, will evaluate the utility of ADS in a distributed EW test environment. The first phase is open air testing to develop a performance baseline for two subsequent test phases. The first distributed test phase employs a linked architecture utilizing DoD's High Level Architecture (HLA) which includes a digital simulation model of the ALQ-131 self protection jammer, threat simulation facilities, and constructive models which support replication of the open air environment. In the second phase, an installed systems test facility is substituted for the digital

model. In both distributed test architectures, system performance data will be compared with live fly data for V&V.

1.2 Test Overview

The SIT will evaluate the utility of using ADS to support cost-effective testing of an integrated missile weapon/launch aircraft system in an operationally realistic scenario. The purpose of the SIT also includes the evaluation of the capability of the JADS Test Control and Analysis Center (TCAC) to control a distributed test of this type and to remotely monitor and analyze test results.

The SIT consists of two phases, each of which culminates in three flight missions. The missions simulate a single shooter aircraft launching an air-to-air missile against a single target aircraft. In the Linked Simulators Phase (LSP), the shooter, target, and missile are all represented by simulators. In the Live Fly Phase (LFP), the shooter and target are represented by live aircraft and the missile by a simulator. This report addresses the LSP results.

Missile systems selected for the SIT are the AIM-9 Sidewinder for the LSP and the AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM) for the LFP. The intent is to extend the SIT results as being representative of the broad class of precision guided munitions systems. Future missile programs which might benefit include the AIM-9X, Joint Direct Attack Munition (JDAM), and Evolved Sea Sparrow Missile (ESSM).

2.0 LSP Test Plan Overview

2.1 LSP Purpose

The LSP applies ADS to an air-to-air missile test program and involves the simulation of an aircraft launching a missile against a maneuvering target aircraft. ADS techniques will be used to link manned flight laboratories representing the aircraft to an air-to-air missile hardware-in-the-loop (HWIL) laboratory representing the missile. This allows the reaction of the target pilot and aircraft countermeasures systems to the missile to be evaluated without endangering the pilot, a key potential benefit of ADS to T&E.

The LSP configuration has both DT and OT characteristics. There is a DT flavor because an HWIL facility is used to simulate the missile. This allows the detailed performance of missile subsystems to be monitored, typical of a DT test. The OT characteristics of the LSP result from the use of aircraft simulators performing operationally realistic engagements.

2.2 LSP Approach

In the LSP, both launch and target aircraft were represented by manned flight laboratories. These laboratories were linked to each other and to an AIM-9M-8/9 HWIL simulation at the Simulation Laboratory (SIMLAB) at China Lake. The launch aircraft laboratory "fired" the AIM-9 in the SIMLAB at the simulated target aircraft. The target received an indication of the missile's presence from a missile warning simulation and could respond by "dropping" flares and maneuvering.

The F/A-18 Weapon System Support Facility (WSSF) at China Lake and the F-14D Weapon System Integration Center (WSIC) at Point Mugu were the shooter and target, respectively. Missile warning system functions were simulated by a digital model at the WSIC. Since the AIM-9 is an IR-seeking missile, flares were used as a countermeasure. The IR signatures and relative motions of the target aircraft and the flares were simulated by IR sources in the SIMLAB. Real-time links between the simulations allowed the players to respond to each other.

The simulation runs were controlled by either the Battle Management Interoperability Center (BMIC) at Point Mugu or the Test Control and Analysis Center (TCAC) in Albuquerque. The Control Center (i.e., either the BMIC or the TCAC) ensured that all nodes were ready for each run and issued the commands to start and stop the runs. Entity state (ES) PDUs from each simulation were processed at the Control Center to provide JADS test controllers and analysts with real-time stealth node viewing of the simulated engagement.

Figure 2.2-1 shows the organizational structure for reporting and coordination during the LSP. Roles and responsibilities of the organizations in the figure are as follows:

- DDT&E: The Deputy Director, Test, Systems Engineering and Evaluation (Test and Evaluation), Office of the Under Secretary of Defense (Acquisition and Technology)

oversees the execution of the JADS JT&E, approves JADS financial requirements, approves the Program Test Plan (PTP), and oversees the analysis and reporting of test results.

- JADS JTD: The JADS Joint Test Director (JTD) oversees the preparation of the PTP, determines the resources necessary to complete the JT&E, establishes liaisons with related programs, conducts the JT&E, and reports test results to DDT&E. Coordinates JADS JT&E funding requirements with the Deputy Director, Test Facilities and Resources (TFR), Office of the Under Secretary of Defense (Acquisition and Technology).

- JADS SIT Team: Responsible to the JADS JTD for planning and conducting the LSP.

- NAWCWPNS: Provides project management of the LSP activities at Pt. Mugu and China Lake, under the direction of the JADS SIT Team. Coordinates requests for AIM-9 test results and program information with the AIM-9 Joint System Program Office (JSPO).

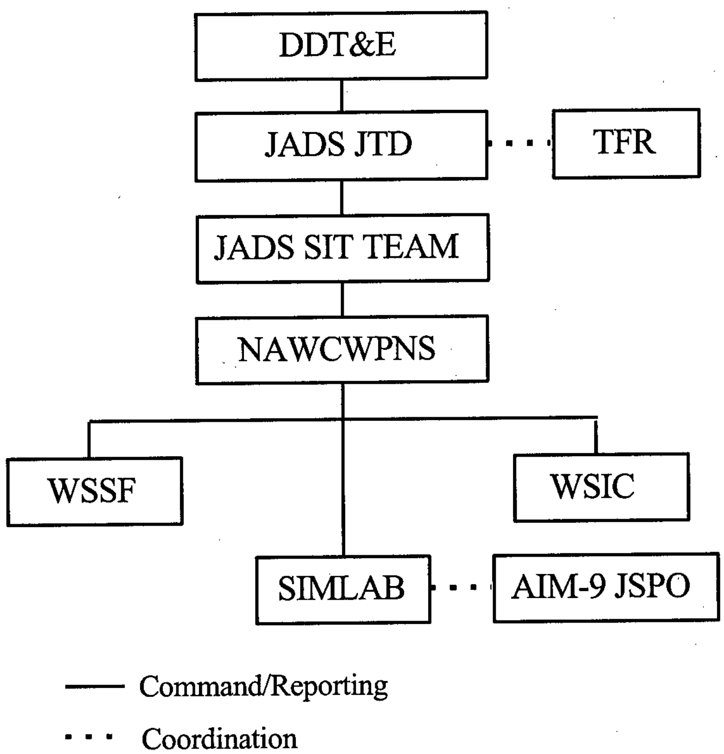

Figure 2.2-1. Linked Simulators Phase Organizational Structure

2.3 LSP Objectives

The overall objective of the LSP was to evaluate the utility of using ADS to support cost-effective testing of an integrated missile weapon/launch aircraft system in an operationally realistic scenario. This top-level objective was accomplished through the following test objectives.

2.3.1 Test Objective 1: Assess the validity of AIM-9 data obtained in the LSP ADS configuration

Under this objective, the SIT LSP assessed the validity of AIM-9M-8/9 data generated in the LSP ADS configuration. This was measured by determining whether or not the LSP was capable of providing valid AIM-9 data. This assessment relied on evaluation of the data by analysts from the AIM-9 test program working together with the JADS analysts to execute the validation procedures for the SIT LFP.

2.3.2 Test Objective 2: Assess utility of LSP ADS configuration for parametric studies

This objective evaluated a potential benefit of the LSP ADS configuration to AIM-9 testing: the ability to conduct parametric studies. The assessment addressed two questions: (1) can valid parametric studies involving countermeasures (CM) effectiveness be conducted with this ADS configuration? (2) if so, is there utility in using this ADS configuration for such studies? The first question was addressed by evaluating the ability to repeat a given scenario with either no changes or with a single parameter varying. The second question was addressed by evaluating the cost and efficiency of executing the parametric studies using the LSP ADS configuration.

2.3.3 Test Objective 3: Assess effect of latency on validity of test results

This objective was to evaluate the effects of latency on test results. An issue here was that when there was significant latency, the different simulation nodes experienced a "different" engagement. Although the AIM-9M-8/9 may continue to successfully intercept the target in the engagement presented to it at its node, this was not exactly the same engagement as that experienced by either the target or the shooter. In other words, with "too much" latency, the planned engagement cannot be executed. Further, "too much" latency will invalidate the results of a reactive scenario (missile and target are reacting to each other).

2.3.4 Test Objective 4: Assess ability of LSP ADS configuration to support AIM-9 testing

This test objective was broken into subobjectives as follows.

2.3.4.1 Test Subobjective 4-1: Assess capability of ADS network to provide bandwidth and connectivity required for LSP tests

This subobjective assessed the ability of the LSP ADS network to support AIM-9 testing when it was operating.

2.3.4.2 Test Subobjective 4-2: Assess the effects of ADS-induced errors on LSP test results validity

The ADS-induced errors were considered included PDUs not received at the appropriate node or received out of order, PDUs corrupted during transmission, and TSPI data errors introduced during the coordinate transformations required for entity state PDUs.

2.3.4.3 Test Subobjective 4-3: Assess adequacy of standard data protocols for LSP test

The SIT LSP utilized standard Distributed Interactive Simulation (DIS) PDUs, where feasible, for transferring information between simulation nodes. This was desirable in order to maintain an open architecture in which other DIS-compliant live test ranges or simulation facilities could replace those used in the LSP in future ADS tests of this type. The adequacy of the standard DIS PDUs to provide the required data accuracy, synchronization, and minimal latency was assessed.

2.3.4.4 Test Subobjective 4-4: Assess reliability, availability, and maintainability of ADS network

This subobjective assessed the degree to which the LSP ADS network was available to support AIM-9 testing and could be maintained.

2.3.4.5 Test Subobjective 4-5: Assess capability for centralized test control and monitoring

This subobjective assessed the capability of the NAWCWPNS BMIC and/or the JADS TCAC to control a distributed test of this type and to remotely monitor and analyze test results.

2.4 LSP Methodology

2.4.1 Scenarios

A baseline scenario was selected from the AIM-9M-8/9 Joint Initial Operational Test and Evaluation (JIOT&E) test series (conducted 17 May 1993 to 29 October 1993). This baseline was profile LPN-15 and is illustrated in Figure 2.4.1-1. In this test, the target began ejecting flares as a CM at a preset time relative to missile launch, rather than on a missile warning cue. The target began a 3.6 g maneuver prior to launch and continued this constant rate turn throughout the engagement. The shooter launched the AIM-9 missile when the proper target aspect was obtained.

This single engagement geometry was the basis for all trials in the LSP. The selection of this baseline from the 16 live fire profiles of the AIM-9M-8/9 JIOT&E was based on three factors: (1) the shooter was an F/A-18, (2) flares were deployed, and (3) sufficient live fire data were available for V&V of the LSP trials. Additional details on LPN-15 are in Appendix A.

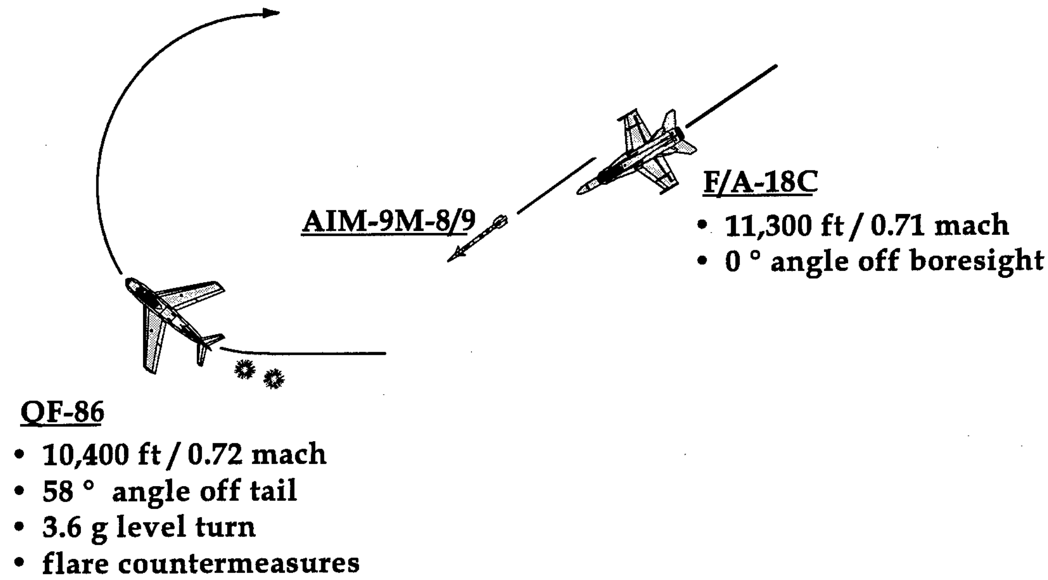

Figure 2.4.1-1. AIM-9M-8/9 Live Fire Profile (LPN-15, 9 June 93)

2.4.2 Planned Test Events

The LSP test objectives were to be accomplished in three blocks of simulation "mission time." These missions are described below.

2.4.2.1 Mission #1: V&V Mission

This mission was designed to accomplish LSP test objectives 1 and 4 and utilized the AIM-9M-8/9 JIOT&E live fire test selected as the baseline, LPN-15, depicted in Figure 2.4.1-1. The pilots in the WSSF and WSIC flight simulators attempted to replicate the live fire profile by using scripted passes and with two variations: Profile V1 (without flare countermeasures) and Profile V2 (with flare countermeasures). Both profiles were baselined on the actual shooter and target parameters and event timing in the LPN-15 scenario. Profile V1 was the verification profile (without flares because not using the SIMLAB flare simulator speeds up the verification passes and the ADS configuration was the same as for the validation profile) and Profile V2 was the validation profile for the V&V Mission. The V&V approach to be used involved comparing the performance of the simulated missile (especially its flyout) to that of the real missile to establish the validity of the ADS configuration.

Table 2.4.2.1-1 summarizes the planned V&V Mission test matrix.

Table 2.4.2.1-1. LSP V&V Mission Planned Test Matrix

Profile/ Repetitions	Simulation Control Mode					ADS Configuration		Remarks
	Auto			Manual		SIMLAB	Linked to	
	Pre-Program	Monte Carlo	Replay	No Flares	Manual Flares	Stand-Alone	WSSF/ WSIC	
RUNS TO BE EXECUTED BEFORE MISSION #1								
V1-APS/ 10	X					X		Verification: Auto replicate live fire profile without flares
V2-APS/ 20	X					X		Characterize variations due to SIMLAB only
V2-AMS/ 25		X				X		Characterize output variations due to initial conditions
RUNS TO BE EXECUTED DURING MISSION #1 - DAY 1								
V1-MNL/ 10				X			X	Verification: Manual replicate live fire profile without flares
V2-MML/ 30					X		X	Validation: Manual replicate live fire profile (LPN-15)
RUNS TO BE EXECUTED DURING MISSION #1 - DAY 2								
V1-MNL/ 10				X			X	Verification: Manual replicate live fire profile without flares
V2-ARL/ 20			X				X	Validation: Auto replay "best" manual replication trial
RUNS TO BE EXECUTED AFTER MISSION #1								
V2-ARS/ 10			X			X		Characterize variations due to SIMLAB only

Features of this test matrix were as follows.

- The two profiles (V1 and V2) were to be exercised in both a "manual" mode and an "automatic" mode, as follows:

  -- Manual Mode. Each simulator was initialized with a pre-established set of initial conditions that have been derived from data produced in the actual LPN-15 flight test. The shooter and target simulators are each flown and controlled by pilots. Each simulator was initially in a "hold" mode (not running dynamically) and loaded with its respective set of initial conditions representative of a flight test being conducted over Holloman AFB (world coordinates and terrain data base). Dynamic running of each simulator was started manually by local operators when its respective "start" command is received from the BMIC/TCAC. Flares were manually released.

  -- Automatic Mode (Simulators Linked). Each simulator was to be locally driven by a playback of the specific recorded subset of data that was pertinent to that simulator. That is, the WSSF was to be driven by shooter data, and the WSIC was to be driven by target data. In this mode there were no pilots flying or controlling the shooter and target simulators (except for manual trigger squeeze by the shooter and manual flare release by the target). The SIMLAB (missile) was driven in each run by inputs from the shooter and target. Control of shooter and target trajectories and timed events (except for trigger squeeze and flare release) were all embedded in the playback data.

- The test matrix was to be executed over a number of days, including runs before and after the Mission #1 test days.

- SIMLAB stan dalone runs were to be done before the Mission #1 test days (Profiles V1-APS and V2-APS). These runs were to be automatic, but without linking the SIMLAB to the other simulators. They were to be executed by either preprogramming the SIMLAB with the LPN-15 profile, including all timed events, or by Monte Carlo sampling of the WSSF and WSIC inputs about the LPN-15 profile. These runs were to be used to (1) verify SIMLAB operation, (2) provide a baseline for missile flyout results from the linked configuration, and (3) develop criteria for initial (i.e., launch) conditions and for the validity of Mission #1 missile flyout results.

- Mission #1 was to be executed over two days.

    -- The first day of Mission #1 was to begin with the verification profile (V1) to ensure the linked configuration was operating properly. Next, the validation profile (V2) was to be manually replicated a number of times (using scripted passes) to obtain a single trial which best replicates the live fire profile, LPN-15.

    -- The sec ond day of Mission #1 again was to begin with the verification profile. Then, the best trial from the previous day was to be automatically replayed a number of times to determine the run-to-run variations in the SIMLAB output when the shooter and target simulator inputs were held constant and when the ADS network was used.

- SIMLAB standalone runs were to be done after the Mission #1 test days (Profile V2-ARS). These runs were to be executed by replaying the same manual run which best replicated LPN-15 to determine the run-to-run variations in the SIMLAB output when the shooter and target simulator inputs were held constant (for "best" manual run conditions) and when the ADS network was not used.

2.4.2.2 Mission #2: Parametric Study Mission

This mission was designed to accomplish LSP test objectives 2 and 4 and was to utilize variations in the live fire test baseline. A key feature in parametric studies was the replay of a given scenario with either no changes or with a single parameter varying.

The basic scenario to be simulated in this mission is shown in Figure 2.4.2.2-1. The engagement was to begin with the same initial conditions as in the baseline, LPN-15 (Fig. 2.4.1-1). The difference was to be that the target now received a missile warning detection cue (either at or after launch) and employed CM based on that cue (rather than at a preset time, as in LPN-15). The CM was to always involve ejection of flares, but could also include evasive maneuvers.

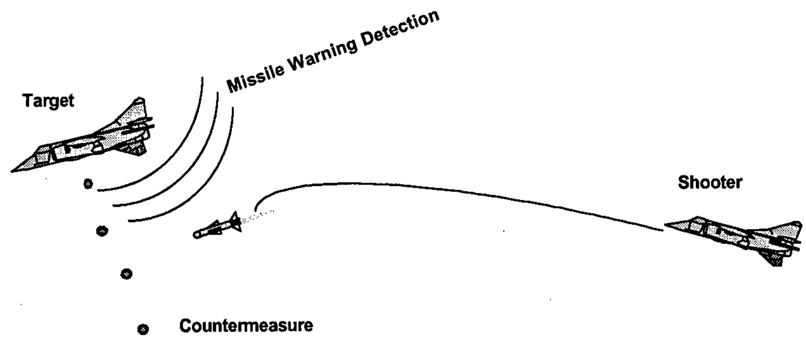

Figure 2.4.2.2-1. Scenario Simulated in Parametric Study Missions

Eight flight profiles were planned for the Parametric Mission. Profile V1 (without flare countermeasures) and Profile V2 (with flare countermeasures) used for the V&V Mission tests were to also be the baseline cases for the Parametric Mission. In this mission Profiles V1 and V2 were to be run exactly as they were in the V&V Mission except they were to be designated as Profiles P1 and P2, respectively. Parametric variations on the target "g" and on the times of the target maneuver, the missile warning cue, and the countermeasures (flare) release were then to be run as Profiles P3 through P8. The test matrix for this mission is given in Table 2.4.2.2-1.

Table 2.4.2.2-1. Parametric Study Mission Test Matrix

Profile/ Repetitions	VARIABLE PARAMETER								REMARKS
	Flare Dispense Time				Target Maneuver Time				
	N/C	+0 s	+2 s	+4 s	N/C	+0 s	+2 s	+4 s	
P1/10					X				Baseline verification profile (V1) No flares
P2/10	X				X				Baseline validation profile (V2) No warning cue
P3/10		X			X				Automatic flare dispense Warning cue at +0 sec
P4/10			X		X				Automatic flare dispense Warning cue at +2 sec
P5/10				X	X				Automatic flare dispense Warning cue at +4 sec
P6/10		X				X			Automatic flare dispense Maneuver: increase turn to 7+ g Warning cue at +0 sec
P7/10			X				X		Automatic flare dispense Maneuver: increase turn to 7+ g Warning cue at +2 sec
P8/10				X				X	Automatic flare dispense Maneuver: increase turn to 7+ g Warning cue at +4 sec

Note: N/C = no change from baseline (V&V) profile

Features of this mission were to be as follows.

- This mission was to utilize the same initial engagement geometry as the V&V Mission. The V&V profile was to be modified by changing the flare release time and by executing an evasive maneuver (in some profiles) after the missile was launched.

- The mission was to begin with repetitions of the verification and the validation passes from the V&V Mission to ensure the test configuration was working properly. Note that the V&V Mission did not utilize warning cues to dispense the flares (they were dispensed at a preset time during the engagement).

- Half of the runs (i.e., 5 runs) for each profile were to be manually flown by the simulator pilots on the first day of Mission #2. The manual trial for each profile which best matched the planned profile was to be automatically replayed on the second day of Mission #2 for the remaining runs.

- The countermeasures (flare release and target maneuver) were to be executed when the warning cue was received by the target.

- Automatic flare release was to be initiated by automatic transmission of a Fire (Flare) PDU from the WSIC.

- In all passes, the target aircraft was already in a 3.6 g turn at missile launch (see Fig. 2.4.1-1). In the runs involving the evasive maneuver, the target pilot was to increase the turn rate by at least 3.4 g to 7 g, or more, upon receipt of the warning cue.

The evaluation criteria here were to be to determine if the engagement can be repeatedly initialized within acceptable tolerances, if the parameters can be varied in a controlled manner, and if the aircraft profiles can be manually replicated to the degree necessary to produce repeatable results when parameters were not varied.

2.4.2.3 Mission #3: Latency Study Mission

An assumption for the Latency Mission was that the V&V Mission was successfully completed and showed that the latency of the baseline configuration was small enough to give valid results. A reactive scenario was to be utilized in which the target reacted to the missile from cues generated by the missile warning system model. Note that this would not be the V&V scenario (which did not involve the missile warning system model). Rather, a scenario was to be selected from the Parametric Mission in which the warning system/CM clearly affected the missile performance.

One flight profile was planned for the Latency Study Mission: the reactive profile selected from the Parametric Study Mission, designated as Profile L1 for the Latency Mission tests. The latency study was to be performed by first replicating this profile for the baseline minimum latency case (inherent system/network latency only) and noting the engagement results for each node. Next the profile was to be repeated with an adjustable time delay at the WSIC node only and again the

engagement results for each node were to be noted. The delay was to be between the network and the WSIC network interface unit (NIU) and was to affect both incoming and outgoing PDUs. The profile was to be repeated with additional increments of time delay at the WSIC node. The test matrix for this mission is given in Table 2.4.2.3-1.

Table 2.4.2.3-1. Latency Study Mission Test Matrix

Profile/ Repetitions	Test 1 - "Coarse" Time Delays Additional Time Delays Inserted at WSIC							REMARKS
	None	#1	#2	#3	#4	#5	#6	
L1-S/5	X							Selected profile run stand-alone in SIMLAB
L1-0/3	X							Selected profile repeated with no additional time delay
L1-1/3		X						
L1-2/3			X					
L1-3/3				X				
L1-4/3					X			
L1-5/3						X		
L1-6/3							X	

Profile/ Repetitions	Test 2 - "Fine" Time Delays Additional Time Delays Inserted at WSIC							REMARKS
	None	#7	#8	#9	#10	#11	#12	
L1-0/3	X							Selected profile repeated with no additional time delay
L1-7/3		X						
L1-8/3			X					
L1-9/3				X				
L1-10/3					X			
L1-11/3						X		
L1-12/3							X	

Features of this mission were to be as follows.

- The mission was to begin with repetitions of the selected profile from the Parametric Mission to ensure the test configuration was working properly. The profile was first to be automatically replayed in the stand-alone SIMLAB configuration (profile L1-S in Table 2.4.2.3-1). Next the profile was to be manuallyreflown by the WSSF and WSIC pilots.

- Profile L1-S also was to serve as a baseline of missile performance data that was free of variations in initial conditions and free of any network latencies. (Note: This test was necessary to establish a "truth" baseline for missile performance because corresponding

missile data from the "baseline" profile from the Parametric Mission would inherently contain the effects of "minimum" latency across the network.)

- The time delays were to be introduced only at the WSIC node. The link between the WSSF and the SIMLAB was not to be affected. The reason for not adding time delays between the WSSF and SIMLAB were that there were two links between these facilities (one for PDU data and one for the MIL-STD-1553 Stores Management System (SMS) data), delays would have to added to both links simultaneously, and significant delays could not be added to the SMS link without affecting the proper operation of the SMS system. Adding delays only at the WSIC node would have simulated the situation of moving the target node to a geographically remote location, while keeping the shooter and missile co-located.

- The values of time delay were to be set in a computer in the WSIC and which was located between the Cisco router and the rest of the WSIC network. This was to be the first processing point in the WSIC encountered by incoming PDUs and the last processing point encountered by outgoing PDUs. The computer was to buffer the PDUs until the preset delay time had elapsed. At that time, the computer was to transmit the PDUs. The actual simulation-computer-to-simulation-computer latency was to be measured before each run by generating a fire flare signal in the WSIC (with generation time stamp) and recording its input into another simulation computer (with input time stamp). Latency between the WSIC and the BMIC/TCAC was to be determined from the time stamp when the Fire (Flare) PDU was recorded in the PDU logger located in the BMIC/TCAC.

- Increments of time delay to be implemented in Test 1 (first day of testing) were to be determined after analysis of the V&V and Parametric Mission results. These were to be coarse time delay steps which should have ensured that significant latency effects were noted in the results. Preliminary analysis indicated that time delay steps between 10 msec and 100 msec should result in the nodes disagreeing on the missile hitting or missing the target.

- Increments of time delay to be implemented in Test 2 (second day of testing) were to be determined after quick-look analysis of the Test 1 results. These were to be fine time delay steps selected to better identify the onset of significant latency effects.

As the time delay was increased, the engagement viewed at each on the four nodes (WSSF, SIMLAB, WSIC, BMIC/TCAC) was expected to increasing differ in terms of launch range, flare release/target maneuver time, and miss distance. Latency was to have clearly affected the engagement outcome if one node perceived a "hit" (missile passed within lethal radius of target) and another node perceived a "miss" (missile passed outside lethal radius of target).

2.4.3 Test Configuration

2.4.3.1 Simulation Sites

WSSF

The launch aircraft was simulated by the F/A-18 WSSF manned flight laboratory. The WSSF is a computer-based laboratory with real integrated avionics used to perform system and subsystem level software development, T&E of the avionics embedded computer systems and their associated Operational Flight Software (OFS). The WSSF is a completely integrated facility capable of supporting system engineering, software engineering, avionics and weapons integration, software maintenance , and incorporation of new systems, technology , and concepts. This facility is the primary tool used to provide quick response investigations of Fleet reported problems, development al testing, V&V, safety of flight testing, correction of errors and deficiencies, investigation of changes, and integration and test of new technology and weapons. Although designed to meet the specific requirements of the F/A-18 aircraft platform, the WSSF generally supports the following test capability requirements: rapid pre- and post-flight testing in support of open air range testing, hot bench mockup accommodation, MIL-STD-1553 avionics bus simulation, MIL-STD-1760 weapons interface bus simulations, high fidelity (6-DOF) flight motion simulations, System-Under-Test (SUT) data collection, real-time interrelated scenario parameter measurement, and real-time performance monitoring, control, and recording for MIL-STD-1553 and -1760 based systems. A variety of test equipment is used including weapons simulators, computer support equipment, 6 -DOF airframe and engine simulations, environment simulations, and avionics sensor simulations to stimulate HWIL throughout a range of operational scenarios. A unique flight test data playback capability exists where data logged in flight can be replayed in the lab oratory for regression testing. The WSSF can also be interconnected with remote NAWC WPNS laboratories and open air ranges to extend the dynamic test capabilities of the facilities.

SIMLAB

The SIMLAB simulated the launch and flyout of the AIM-9. The active guidance of the AIM-9 will be simulated by stimulating the AIM-9 seeker with an IR scene which dynamically responds to the target aircraft maneuvers. The SIMLAB is a fully equipped, state-of-the-art, HWIL simulation facility for testing actual missile hardware in an environment that closely simulates a real-world flight. The laboratory consists of a Carco three axis flight motion simulator, high speed simulation computers, and targeting systems for generating radar and infrared signatures to simulate targets and countermeasures. These facilities are used for system level evaluation of full closed-loop missile performance, including sensor, guidance and control, signal processing, and countermeasures/counter-countermeasures capability.

WSIC

The target aircraft was simulated by the WSIC F-14D manned flight laboratory. The WSIC is a systems level test facility for the F-14D weapons control systems. This facility is used to measure

the functionality of F-14D tactical software, to support hardware integration testing , and to support the system level software integration of subsystem and module software packages developed by prime contractors and government activities. The F-14 WSIC provides a complete simulation and testing center for the F-14; secondary functions include data reduction and support to additional projects from the Defense Modeling and Simulation Organization (DMSO) and the Advanced Research Projects Agency (ARPA). The center provides test beds to develop new F-14 tactical software, integrate new weapons systems into the F-14 aircraft , and perform V&V of the F-14 tactical software. These functions are performed in any of four developmental environments: full software simulation, stand-alone (single-subsystem, simulated system), partial integration (groups of subsystems with the remainder simulated), and full integration. Each laboratory uses real-time simulations to stimulate weapon system inputs in a controlled laboratory environment. Dynamic real-time mathematical models provide Weapon Replacement Assemblies (WRAs) not used in the laboratory for user convenience. Real-time and post-flight data monitoring and analysis tools are available for users to completely ascertain system performance. The WSIC supports off-site RDT&E projects using dedicated T1 lines as well a Red Gateway on the Defense Simulations Internet(DSI) to provide the necessary laboratory internetting.

2.4.3.2 LSP Network

The LSP test configuration is shown in Figure 2.4.3.2-1, and the information flow during the LSP is shown in Figure 2.4.3.2-1. Each simulation node was DIS compliant and encrypted. The network data exchange protocol was DIS Version 2.0.4, except for the Stores Management System (SMS) data exchange between the F/A-18 WSSF and the AIM -9 SIMLAB. This link used the MIL-STD-1553 protocol, because no suitable DIS protocol exists for these data and because this exchange was only between the WSSF and the SIMLAB.

Before launch, the WSSF and the SIMLAB exchanged SMS data over a dedicated link. This link represented an extension of the F/A-18 avionics bus consisting of MIL-STD-1553 data [1]. The SMS computer, LAU-7 launcher rail, and the umbilical cable between it and the AIM-9 were all in the SIMLAB. The launch signal from the F/A-18 passed over the SMS link to command the launch sequence in the SIMLAB. When the missile battery squib firing was detected, a Fire (Missile) PDU was generated in the SIMLAB.

State data for each of the players was in the form of ES PDUs generated at each player's node and passed to all other nodes. The target ES PDUs were used in the SIMLAB to dynamically control the representation of the target in the IR scene presented to the AIM-9 seeker. As the AIM-9 underwent its simulated flyout, its trajectory information (position versus time) was converted into ES PDUs in the SIMLAB. When the SIMLAB stopped sending out missile ES PDUs, a Detonation PDU was generated in the SIMLAB.

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[1] The prelaunch SMS data exchange between the WSSF and the SIMLAB shall be as currently implemented per the F/A-18 WSSF MIL-STD-1553 Networking System (MNS-1) Interface Control Document (ICD) dated 14 March 1996.

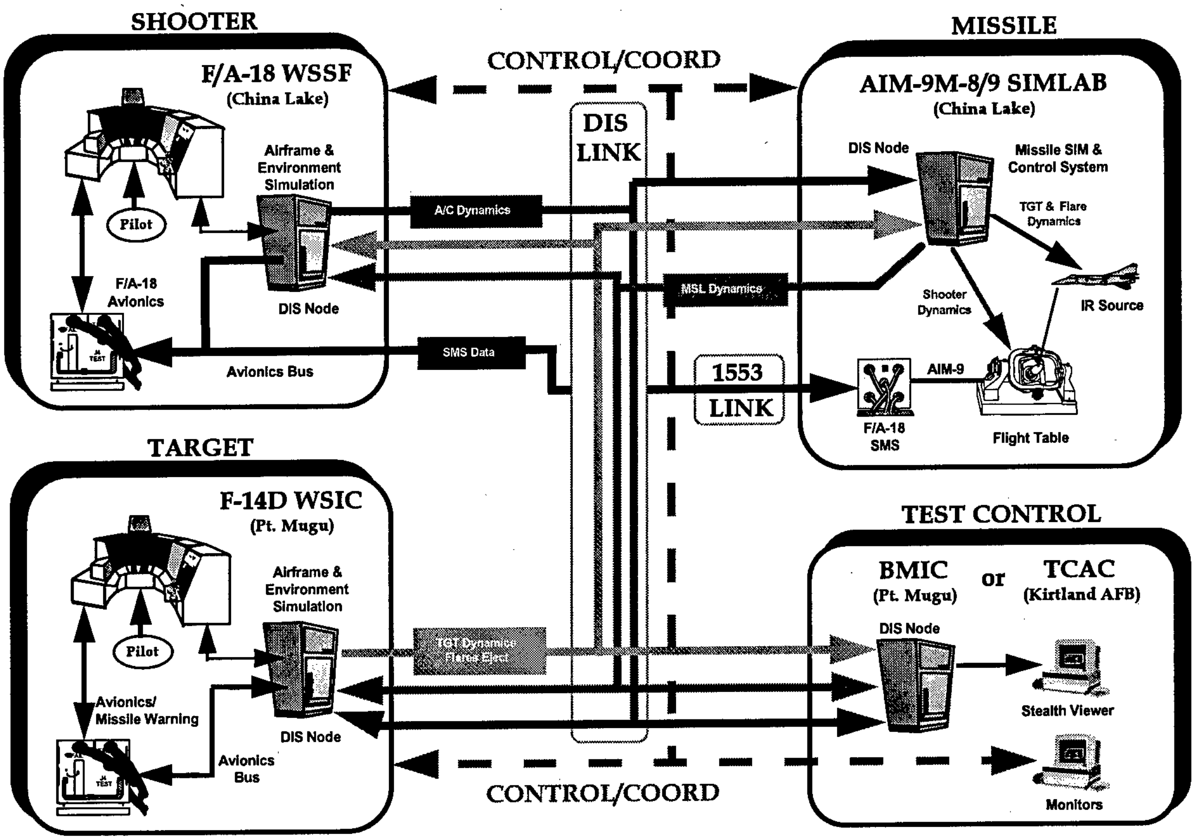


Figure 2.4.3.2-1. Linked Simulators Phase Test Configuration

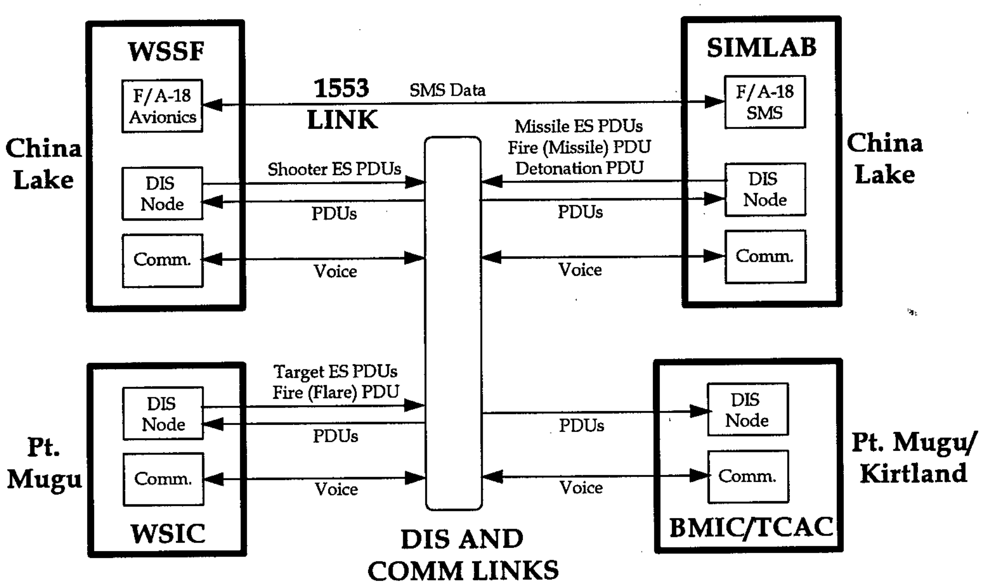


Figure 2.4.3.2-2. Linked Simulators Phase Network Information Diagram

The detailed network hardware diagram for the LSP is given in Appendix D, Annex 2.

2.4.3.3 Test Control and Monitoring

The LSP investigated four areas of test control: aircraft control, test article and associated system monitoring, communications, and test procedures. The thrust of the test control investigation was to determine how much of the control function should reside at the individual nodes, how much needs to be at the central control node, and what communications were required between the nodes.

The LSP used only one basic engagement geometry. The initial setup (position, attitude, altitude, airspeed and heading) for this geometry was programmed into each simulator. At the beginning of each run, each simulator could be reset to these initial conditions. During the manual passes, the aircraft controller at the BMIC/TCAC used a two-dimensional display to vector the aircraft into positions from which the pilots could fly the final portion of the intercept to a firing position. This aircraft positions, altitude, and airspeed were displayed, and "tails" were used to provide a position history.

To control the test, two-way communications with the pilots, the person monitoring the equipment at each site, and various analysts were required. For the LSP, open telephone lines and a low bit rate video system were used. The test controller started and stopped each run using voice commands. The status of each node was also reported using the voice circuits.

Test control procedures, test cards, and checklists are at Appendix E of this document.

2.4.3.4 Instrumentation

The same instrumentation at a given site was used for all LSP missions (see Table 2.4.3.4-1). Time stamp considerations were as follows:

- Both China Lake and Point Mugu use cesium clocks as time sources. These clocks are corrected periodically to Greenwich Mean Time (GMT) which is provided by the Global Positioning System (GPS) satellite constellation. A coded time signal is broadcast throughout each range. Each facility which requires accurate time stamps has an antenna which receives this signal. Propagation delays are accounted for and the signal in IRIG format is available in the facility. For the SIT the IRIG-B signal is converted to serial and provided as an input to the data loggers.

- The time source is accurate to within 150 nanoseconds of GMT. The serial signal is used by the Silicon Graphics, Inc. (SGI) Indy computers in consonance with the drift file to provide a time source accurate to the order of 100 microseconds. Since all of the latencies measured will be greater than 10-20 milliseconds it was decided that a time source accuracy of 1 millisecond would be sufficient for SIT purposes. This also permitted using standard IRIG, GPS, and DIS PDU formats for time stamps since the least significant bit in each of these formats provides a precision of 1 millisecond.

Table 2.4.3.4-1. LSP Instrumentation Requirements

Location	Description	Function
F/A-18 WSSF	IRIG-B translator/generator	Test coordination
	4 mm tape recorder	Data transfer
	HUD video camera	Capture HUD displays
	HUD video recorder (VCR)	Capture HUD displays
	DIS DataLogger	Record PDUs
	DataLogger software	Record PDUs
F-14D WSIC	IRIG-B translator/generator	Test coordination
	4 mm tape recorder	Data transfer
	HUD video camera	Capture HUD displays
	HUD video recorder (VCR)	Capture HUD displays
	DIS DataLogger	Record PDUs
	DataLogger software	Record PDUs
SIMLAB	IRIG-B translator/generator	Test coordination
	4 mm tape recorder	Data transfer
	9 - track, 1/2" magnetic tape recorder	Record hi-fidelity simulation data
	Telemetry pack (AIM-9M-8/9)	Acquire missile TM data
	Real-time chart recorders/displays	Test monitor
	DIS DataLogger	Record PDUs
	DataLogger software	Record PDUs
TCAC	IRIG-B translator/generator	Test coordination
	Stealth Viewer	Test coordination
	Video camera(s)	Capture displays
	Video recorder(s)	Capture displays
	DIS DataLogger	Record PDUs
	DataLogger software	Record PDUs

2.4.4 LSP Assumptions and Limitations

The following limitations apply:

- The SIMLAB's IR target presentation system presented the target as a point IR source. This limited the validity of terminal engagement results when the target should be represented by an extended and structured IR source.
- The simulations at the different laboratories could not be synchronized. This included lack of synchronization in the start of the simulations and in the individual frames of the simulations. This prevented reliable performance of the automatic replay runs.
- The manned aircraft laboratories did not have totally realistic flying/handling qualities when compared to the actual aircraft and did not have sophisticated visual presentation systems. This limited their use to scripted, rather than free play, scenarios.

- The missile HWIL laboratory did not allow a wide range of motion in order to handle large angles off and/or large angle rates. This also precluded the use of free play scenarios.

2.5 LSP Planned Schedule

2.5.1 Top Level Schedule

The schedule of top level tasks for the LSP is given in Figure 2.5.1-1. The following tasks are indicated in the schedule:

Task 1 Pre-Test Documentati on: Prepare documentation of test definition, requirements, and plans. Joint JADS/ NAWCWPNS task.
Task 2 Infrastructure Development: Implement the NAWCWPNS Real-Time Network (NRNet) to link the NAWCWPNS facilities for the LSP. NAWCWPNS task.
Task 3 SIMLAB Enhancement: Modify SIMLAB, as required. NAWCWPNS task.
Task 4 WSIC Enhancement: Modify WSIC, as required. NAWCWPNS task.
Task 5 WSSF Enhancement: Modify WSSF, as required. NAWCWPNS task.
Task 6 BMIC Preparations: Prepare BMIC as the control node for Mission #1. Joint task.
Task 7 Integration Testing: Verify links between facilities and rehearse missions. Joint task.
Task 8 TCAC Preparations: Prepare TCAC as the control node for Missions #2 and #3. JADS task.
Task 9 Test Missions: Execute the three LSP missions. Joint task.
Task 10 Post-Test Documentation: Document the results of the LSP execution. Joint task.

			FY96			FY97	
Task Name	Start	Finish	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2
1 Pre-Test Documentation	1/15/96	8/1/96					
2 Infrastructure Development	2/5/96	6/21/96					
3 SIMLAB Enhancement	2/14/96	6/21/96					
4 WSIC Enhancement	2/14/96	6/21/96					
5 WSSF Enhancement	2/5/96	5/31/96					
6 BMIC Preparations	4/10/96	8/1/96					
7 Integration Testing	6/3/96	8/1/96					
8 TCAC Preparations	8/16/96	9/27/96					
9 Test Missions	8/5/96	12/3/96					
10 Post-Test Documentation	8/9/96	3/31/97					

Figure 2.5.1-1. Linked Simulators Phase Activities and Schedule

2.5.2 Pre-Test Detailed Schedule

The following top level tasks in Figure 2.5.1-1 are pre-test tasks:

Task 1 Pre-Test Documentation
Task 2 Infrastructure Development
Task 3 SIMLAB Enhancement
Task 4 WSIC Enhancement
Task 5 WSSF Enhancement
Task 6 BMIC Preparations
Task 7 Integration Testing
Task 8 TCAC Preparations

The detailed schedule of each of these follows.

Task 1 Pre-Test Documentation. The detailed schedule for this task is shown in Figure 2.5.2-1. The following tasks and activities are indicated in the schedule:

1.1 Integration Test Plan: NAWCWPNS develop the ITP which provides a description of data and functional requirements, modifications of NAWCWPNS test facilities, tasking, an implementation schedule, and a list of major milestones for the LSP effort.

1.2 V&V Plan: NAWCWPNS develop the V&V Plan which documents the detailed approach for verifying the LSP ADS configuration during pre-test buildup and for validating the AIM-9M-8/9 results obtained during Mission #1.

1.3 Laboratory Test Plan: NAWCWPNS develop the LTP whi ch provides a more detailed test plan, including test method and conduct, data reduction and analysis, and requirements for data and instrumentation.

1.4 Test Activity Plan: JADS prepare the TAP which combines JADS activities and objectives with NAWCWPNS plans and activities.

			FY96		
Task Name	Start	Finish	Qtr 2	Qtr 3	Qtr 4
1 Pre-Test Documentation	**1/15/96**	**8/1/96**			
1.1 Integration Test Plan	1/15/96	4/12/96			
1.2 V&V Plan	2/26/96	4/12/96			
1.3 Laboratory Test Plan	3/4/96	5/15/96			
1.4 Test Activity Plan	3/1/96	8/1/96			

Figure 2.5.2-1. Pre-Test Documentation Activities and Schedule

Task 2 Infrastructure Development. The detailed schedule for this task is shown in Figure 2.5.2-2. The following tasks and activities are indicated in the schedule:

2.1 Implement H/W and Comm Links: Hardware and communications links at China Lake and at Pt. Mugu shall be implemented by NAWCWPNS using NRNet. The T1 linking China Lake to Pt. Mugu is already in place. Routers and CSU/DSU will be procured and installed as required.

2.2 Program Routers: The NRNet routers will be set up to run TCP/IP.

2.3 Implement Secure Operations: An NRNet Memorandum of Agreement (MOA) shall be developed by NAWCWPNS to establish agreement among the facilities concerning secure operation and cryptographic (COMSEC) keying material handling. COMSEC keying material will be issued to each facility to support secure operations.

2.4 NRNet Checkout: Implementation of the NRNet for the LSP will be verified by checkout of the links between the facilities.

			FY96		
Task Name	**Start**	**Finish**	Qtr 2	Qtr 3	Qtr 4
2 Infrastructure Development	**2/5/96**	**6/21/96**			
2.1 Implement H/W and Comm Links	2/5/96	4/19/96			
2.2 Program Routers	2/19/96	6/21/96			
2.3 Implement Secure Operations	2/19/96	4/19/96			
2.4 NRNet Checkout	5/1/96	6/21/96			

Figure 2.5.2-2. Infrastructure Development Activities and Schedule

Task 3 SIMLAB Enhancement. The detailed schedule for this task is shown in Figure 2.5.2-3. The following tasks and activities are indicated in the schedule:

3.1 Develop/Install DIS Node: To support the LSP, a DIS node will be added to the SIMLAB IR#1 Facility. An HP 735 computer system will be procured and installed as the SIMLAB's DIS node. Modifications will be made to the existing simulation to support the addition of the DIS communication requirement. Simulation Specific Component (SSC) code will be developed to provide the signal interface between the simulation system and the DIS node's NIU software.

3.2 Calibrate Facility: The operating envelope of IR#1 will be defined to verify the ability of the simulation to run the LSP scenarios. The IR target presentation system, the flare generator system, and the Carco three axis flight simulator will be calibrated.

3.3 Procure/Install Seeker: An AIM-9M-8/9 seeker will be procured and installed in the IR#1 facility.

3.4 Develop Data Logging Capability: Simulation software will be modified, as required, to support data logging and quick-look data capability.

3.5 Internal Testing: The SIMLAB modifications will be verified during internal testing at the facility.

Task Name	Start	Finish	FY96 Qtr 2	FY96 Qtr 3	FY96 Qtr 4
3 SIMLAB Enhancement	**2/14/96**	**6/21/96**			
3.1 Develop/Install DIS Node	2/14/96	5/8/96			
3.2 Calibrate Facility	2/14/96	6/21/96			
3.3 Procure/Install Seeker	4/5/96	5/1/96			
3.4 Develop Data Logging Capability	4/16/96	5/24/96			
3.5 Internal Testing	5/8/96	5/29/96			

Figure 2.5.2-3. SIMLAB Enhancement Activities and Schedule

Task 4 WSIC Enhancement. The detailed schedule for this task is shown in Figure 2.5.2-4. The following tasks and activities are indicated in the schedule:

4.1 Develop/Install DIS Node: To support the LSP, a DIS node will be added to the WSIC Facility. Modifications will be made to the existing simulation to support the addition of the DIS communication requirement. SSC code will be developed to provide the signal interface between the simulation system and the DIS node's NIU software.

4.2 Design/Program Data Exch Node: The Universal Data Exchange (UDX) in the WSIC shall be modified to accept F-14D 1553 bus information required for the LSP. The UDX will also be modified to convert the 1553 bus data into units required by the SSC code in the NIU.

4.3 Develop Data Logging Capability: Simulation software will be modifie d, as required, to support data logging and recording capability

4.4 Develop MWS S/W & H/W: Code will be developed to model functioning of the missile warning system. Hardware will be fabricated to indicate which quadrant the missile is approaching from and to provide a warning buzzer to the WSIC pilot.

4.5 Internal Testing: The WSIC modifications will be verified during internal testing at the facility.

Task Name	Start	Finish	FY96 Qtr 2	FY96 Qtr 3	FY96 Qtr 4
4 WSIC Enhancement	**2/14/96**	**6/21/96**			
4.1 Develop/Install DIS Node	2/14/96	5/15/96			
4.2 Design/Program Data Exch Node	2/21/96	5/24/96			
4.3 Develop Data Logging Capability	4/16/96	5/24/96			
4.4 Develop MWS H/W & S/W	4/3/96	6/21/96			
4.5 Internal Testing	5/6/96	6/21/96			

Figure 2.5.2-4. WSIC Enhancement Activities and Schedule

Task 5 WSSF Enhancement. The detailed schedule for this task is shown in Figure 2.5.2-5. The following tasks and activities are indicated in the schedule:

5.1 Define Requirements: Requirements for WSSF to support LSP will be defined.

5.2 Modify DIS Node: The existing DIS node at the WSSF will be modified, as required, to support the LSP. The simulation system and the SSC code will be modified to support the PDUs required for the LSP.

5.3 Develop Data Logging Capability: Data recording specification files will be developed to direct data recording operations throughout a test scenario.

5.4 Internal Testing: The WSSF modifications will be verified during internal testing at the facility.

			FY96		
Task Name	**Start**	**Finish**	Qtr 2	Qtr 3	Qtr 4
5 WSSF Enhancement	**2/5/96**	**5/31/96**			
5.1 Define Requirements	2/5/96	4/3/96			
5.2 Modify DIS Node	3/6/96	5/15/96			
5.3 Develop Data Logging Capability	5/15/96	5/31/96			
5.4 Internal Testing	5/15/96	5/31/96			

Figure 2.5.2-5. WSSF Enhancement Activities and Schedule

Task 6 BMIC Preparations. The detailed schedule for this task is shown in Figure 2.5.2-6. The following tasks and activities are indicated in the schedule:

6.1 Define Requirements: Requirements for test control and monitoring using the BMIC will be defined, including a test control concept of operations. The concept of operations will be consistent with utilization of the TCAC for test control.

6.2 Install/Configure H/W & S/W: Hardware and software needed for test control and monitoring will be installed and/or configured in the BMIC and at the simulation nodes, if required. The BMIC will be connected to the NRNet configuration linking the simulation facilities.

6.3 Develop Control Procedures: Procedures for controlling the LSP missions will be developed and documented.

6.4 Checkout & Testing: The BMIC modifications will be verified during internal testing at the facility.

			FY96		FY97
Task Name	**Start**	**Finish**	Qtr 3	Qtr 4	Qtr 1
6 BMIC Preparations	**4/10/96**	**8/1/96**			
6.1 Define Requirements	4/10/96	5/31/96			
6.2 Install/Configure H/W & S/W	7/15/96	7/19/96			
6.3 Develop Control Procedures	7/1/96	8/1/96			
6.4 Checkout & Testing	7/15/96	8/1/96			

Figure 2.5.2-6. BMIC Preparations Activities and Schedule

Task 7 Integration Testing. The detailed schedule for this task is shown in Figure 2.5.2-7. The following tasks and activities are indicated in the schedule:

7.1 Develop Test Procedures: Integrated procedures for executing the LSP missions will be developed and used during integration testing and checkout activities. Each facility will develop their own test procedures, and these will be coordinated among the laboratories using an iterative process. The final checkout period will be used to integrate and consolidate the test procedures.

7.2 WSSF/SIMLAB Exch PDUs: The link between the WSSF and SIMLAB will be verified, along with the capability to exchange and record the required data.

7.3 WSSF/WSIC Exch PDUs: The link between the WSSF and WSIC will be verified, along with the capability to exchange and record the required data.

7.4 All Nodes Exch PDUs: The links between the WSSF, SIMLAB, WSIC, and BMIC will be verified, along with the capability to exchange and record the required data.

7.5 Dry Runs w/o Test Control: The LSP configuration will be exercised without the BMIC test control procedures. Test procedures will be refined.

7.6 Dry Runs w/ Test Control: The ability of the BMIC to control the simulation facilities will be verified. The integrated test procedures, including control procedures, will be exercised for the final pre-mission checkout and verification.

			FY96		FY97
Task Name	**Start**	**Finish**	Qtr 3	Qtr 4	Qtr 1
7 Integration Testing	**6/3/96**	**8/1/96**			
7.1 Develop Test Procedures	6/3/96	8/1/96			
7.2 WSSF/SIMLAB Exch PDUs	6/3/96	6/14/96			
7.3 WSSF/WSIC Exch PDUs	6/24/96	6/28/96			
7.4 All Nodes Exch PDUs	7/1/96	7/12/96			
7.5 Dry Runs w/o Test Control	7/15/96	7/17/96			
7.6 Dry Runs w/ Test Control	7/18/96	7/19/96			

Figure 2.5.2-7. Integration Testing Activities and Schedule

Task 8 TCAC Preparations. The detailed schedule for this task is shown in Figure 2.5.2-8. The following tasks and activities are indicated in the schedule:

8.1 Install/Configure H/W & S/W: Hardware and software needed for test control and monitoring of Missions #2 and #3 will be installed and/or configured in the TCAC. The BMIC will be decommissioned as the control node.

8.2 Checkout & Testing: The TCAC modifications will be verified during internal testing at the facility

8.3 Connect T1: The commercial T1 between the TCAC and Pt. Mugu will be leased and connected.

8.4 Baseline Network Performance: The T1 link between the TCAC and Pt. Mugu will be tested, and the network performance will be characterized.

Task Name	Start	Finish	FY96	FY97	
			Qtr 4	Qtr 1	Qtr 2
8 TCAC Preparations	**8/16/96**	**9/27/96**			
8.1 Install/Configure H/W & S/W	8/16/96	9/5/96			
8.2 Checkout & Testing	9/3/96	9/20/96			
8.3 Connect T1	9/3/96	9/20/96			
8.4 Baseline Network Performance	9/23/96	9/27/96			

Figure 2.5.2-8. TCAC Preparations Activities and Schedule

2.5.3 Test Conduct Detailed Schedule

The following top level task in Figure 2.5.1-1 is a test conduct task:

Task 9 Test Missions. The detailed schedule for this task is shown in Figure 2.5.3-1. The three missions are indicated in the schedule.

Task Name	Start	Finish	FY96	FY97	
			Qtr 4	Qtr 1	Qtr 2
9 Test Missions	**8/5/96**	**12/3/96**			
9.1 Mission #1	**8/5/96**	**8/29/96**			
9.1.1 Test Execution	8/5/96	8/9/96			
9.1.2 Quick-Look Report	8/9/96	8/14/96			
9.1.3 Analysis	8/9/96	8/29/96			
9.2 Mission #2	**10/7/96**	**10/25/96**			
9.2.1 Test Execution	10/7/96	10/11/96			
9.2.2 Quick-Look Report	10/11/96	10/16/96			
9.2.3 Analysis	10/11/96	10/25/96			
9.3 Mission #3	**10/29/96**	**12/3/96**			
9.3.1 Test Execution	10/29/96	11/1/96			
9.3.2 Quick-Look Report	11/1/96	11/6/96			
9.3.3 Analysis	11/1/96	12/3/96			

Figure 2.5.3-1. Test Missions Activities and Schedule

Each test mission consists of the following activities:

9.X.1 Test Execution: Each mission will consume two days. The first day will start with a dry run to check connectivity and operation of all nodes. Upon successful completion of the dry run, the actual mission will begin. Each

mission will execute the corresponding test matrix in order to accomplish the test objectives for the mission. Test control and monitoring will be exercised from the BMIC in Mission #1 and the TCAC in Missions #2 and #3.

9.X.2 Quick-Look Report: A quick-look report will be prepared after each mission and will summarize performance of the overall mission.

9.X.3 Analysis: Detailed analysis will be performed to verify that all test objectives were met and to prepare for subsequent missions.

2.5.4 Post-Test Detailed Schedule

The following top level task in Figure 2.5.1-1 is a post-test task:

Task 10 Post-Test Documentation. The detailed schedule for this task is shown in Figure 2.5.4-1. Work on the final report will begin as soon as results from Mission #1 are available. NAWCWPNS will provide JADS with a final report after all missions have been completed and the data analyzed. JADS will combine the NAWCWPNS report with the results of additional JADS analysis for the JADS Final Report. The final report will be a compilation of quick-look and detailed analysis, V&V documentation, lessons learned, conclusions, and recommendations.

			FY96	FY97	
Task Name	**Start**	**Finish**	Qtr 4	Qtr 1	Qtr 2
10 Post-Test Documentation	**8/9/96**	**3/31/97**			
10.1 NAWCWPNS Final Report	8/9/96	1/2/97			
10.2 JADS Final Report	1/2/97	3/31/97			

Figure 2.5.4-1. Post-Test Documentation Activities and Schedule

3.0 LSP Execution Results

This section describes mission rehearsal and execution activities, to include conclusions, with emphasis on the deviations from the planned test approach.

3.1 Mission Rehearsal

3.1.1 Mission Rehearsal Plan

The objective of the Mission Rehearsal was to prepare for the V&V Mission, and the test matrix was the same as for the V&V Mission (Day 1 and Day 2 runs in Table 2.4.2.1-1). There were two sets of V&V trials: one set manual, the other automatic. The automatic trials were to use recorded data to replay a single previously flown simulation engagement. The manual runs included trials with and without flares, and the automatic runs were with flares only. Test control was exercised from the Battle Management Interoperability Center (BMIC) at Pt Mugu CA. Test schedule slips due to simulator and networking integration problems caused the Mission Rehearsal period to move into a period originally scheduled for testing rather than rehearsal.

3.1.2 Mission Rehearsal Results

The Mission Rehearsal took place on 27 and 28 August 1996. Over the two day period, 107 trials were attempted. There were 19 manual runs with no flares, 54 manual runs with flares, and 34 automatic runs with flares. A trial was judged to be completed if there was a successful missile launch and a complete missile flyout. A defined shot box was established prior to rehearsal missions (Table 4.1.1.2-1). A trial could be complete without being in the shot box. Of the 19 benign manual runs, 14 were completed, and of those, 9 were in the box (all 5 runs which were out of the box occurred on the first day of testing when the test controller and shooter pilot were adjusting simulator starting positions and shoot cues to achieve the LPN-15 launch conditions). Of the 54 manual trials with flares, 38 were complete, and 36 were in the box. Of the 34 automatic trials with flares, 27 were complete, and 24 were in the box. The automated runs did not work as planned, because the flight simulators were not designed to support automatic, rather than manual, inputs. Using "in the box" as the sole success criterion, 69 of the 107, or about 65% of the attempted trials were successful. From a qualitative perspective, missile flyout representation in the ADS environment was not consistent with live missile behavior. The HWIL missile lofted after launch in the distributed environment; the real AIM-9 missile in LPN-15 (and in standalone HWIL simulations), under similar launch conditions, did not demonstrate that behavior. Results are summarized in Table 3.1.2-1.

Table 3.1.2-1. Summary of Runs in Mission Rehearsal

Manual/Auto	Flares	Attempts	Complete	In the box	% in the box
M	No	19	14	9	47%
M	Yes	54	38	36	67%
A	Yes	34	27	24	71%
Total		107	79	69	64%

Reasons for not completing, or aborting, the runs included: WSSF not sending out PDUs, shooter losing lock before or at launch, WSSF not properly reset, SIMLAB not properly reset before the run, SIMLAB losing shooter PDUs before launch, no missile launch, and WSSF not starting.

3.1.3 Mission Rehearsal Conclusions

- Test procedures, including control procedures, worked very well. The test controller and pilots were able to achieve reproducible launch conditions within a minimal number of trial runs. However, step calls were deemed necessary by NAWCWPNS for the remaining missions due to OPSEC concerns. The step calls replaced certain actions directed by the test controller during the runs with step numbers.

- The automatic replay runs were unable to achieve their objective: precise replication of launch conditions and target trajectory. This resulted because several manual actions were required: manual and independent starts of the WSSF and WSIC, manual trigger squeeze by the shooter pilot, and manual initiation of the flare simulator. As a result, the automatic replay runs were removed from the V&V Mission and Parametric Study Mission test matrices.

- The manual V2 runs produced sufficient data for evaluating the reproducibility of profile conditions by the pilots. This is the major consideration in achieving Test Objective 2.

- The simulated missile flyout in the SIMLAB was judged to be anomalous by the AIM-9 expert. The shooter was about 900 feet higher in altitude than the target, and the missile should have steadily lost altitude during its flyout. Instead, the missile "lofted" to an altitude above the shooter before losing altitude and guiding to the target.

- Preparation for testing often takes longer than planned. (Stated another way, planners have a tendency to underestimate the schedule requirements for set-up and checkout.)

- Test rehearsal periods need to be followed by a lab or experimental period, during which fixes and corrections (for things like the lofting problem) are explored in a linked environment. An experimental period was conducted on 22 Oct to try to fix the lofting problem. Many fixes cannot be satisfactorily explored in unlinked conditions.

3.2 V&V Mission

3.2.1 V&V Mission Plan

The primary objective of the V&V Mission was to accomplish V&V of the LSP configuration, and most of the runs were dedicated to that purpose. The V&V runs followed the manual runs for the V&V Mission test matrix (Day 1 runs in Table 2.4.2.1-1). A second set of modified trials were specifically aimed at investigating the missile lofting problem discovered in the August rehearsals. The modified runs explored flyout behavior when the shooter nose was above or

below the original (essentially boresight) test conditions at launch. A final set of trials were performed to verify the ability of the WSIC to generate a FIRE (Flare) PDU immediately upon receipt of the missile launch cue and the ability of the SIMLAB to use the FIRE (Flare) PDU to initiate the flare simulator (profile P3 from the Parametric Study Mission, Table 2.4.2.2-1). Because of Mission Rehearsal results, automated runs were eliminated from the test, and the test period was reduced from two days to one day. The modified test matrix is given in Table 3.2.1-1. Test control was exercised from the Test Control and Analysis Center (TCAC) in Albuquerque, NM.

Table 3.2.1-1. Modified V&V Mission Test Matrix

Profile/ Repetitions	Flare Configuration			Remarks
	No Flares	Manual Flares	Auto Flares	
V1/10	X			Verification: Manual replicate live fire profile without flares
V2/20		X		Validation: Manual replicate live fire profile (LPN-15)
Modified V2/2		X		Lofting Study: Shooter nose above boresight and to left
Modified V2/2		X		Lofting Study: Shooter nose above boresight and to right
Modified V2/2		X		Lofting Study: Shooter nose below boresight and to left
Modified V2/2		X		Lofting Study: Shooter nose below boresight and to right
P3/2			X	Verify ability to execute Parametric Mission runs

3.2.2 V&V Mission Results

The V&V Mission was performed on 29 October 1996. There were 6 manual V1 runs without flares, all were complete, and 4 were in the box. There were 21 manual V2 runs with flares. Of those, 13 were complete, and 10 were in the box. There were 6 modified manual runs, with flares, designed to explore the lofting problem. Of those, only two were complete, but the other four contained enough of the initial flyout data to support the lofting investigation. Finally, there were 3 manual P3 runs to verify automatic flare initiation. Of those, only one was complete with successful flare initiation. Excluding the lofting experiment and automatic flare initiation runs (these did not attempt to launch in the box), 14 of 27 V&V runs were in the box for an apparent success rate of approximately 52%. Results for the V&V runs are summarized in Table 3.2.2-1.

Reasons for not completing, or aborting, the V&V runs included: WSIC not running and SIMLAB not properly reset before run. During the automatic flare initiation runs, the first attempt did not initiate the flares because the SIMLAB code had not been switched to allow FIRE

(Flare) PDU initiation of the flares on the first run. This was fixed for the second and third attempts. However, the second attempt was aborted because the shooter was not seeing the target.

Table 3.2.2-1. Summary of V&V Runs in V&V Mission

Manual/Auto	Flares	Attempts	Complete	In the box	% in the box
M	No	6	6	4	67%
M	Yes	21	13	10	48%
Total		27	19	14	52%

3.2.3 V&V Mission Conclusions

- The V&V objective could not be fully accomplished. The missile lofting problem had not been fixed, so that the missile flyouts were still judged to be invalid.

- The lofting investigation showed that lofting still occurred even when the shooter's nose was pointed well below the target. Hence, it was concluded that the shooter attitude at launch was not causing or contributing to the lofting.

- The target latitude received at the SIMLAB was compared to that computed in the missile simulation by integrating the target's north velocity component. The result was that the simulation computed a target location that steadily diverged from the value received directly from the WSIC. The largest value of divergence was always at the end of the missile flyout and ranged from 150 to 300 feet (the latitude computed by the missile simulation was north of the value from the WSIC by these amounts).

- Latency values between nodes varied significantly; the values were not statistically well behaved. Latency values were largely associated with processing, to include buffering, delays. Latency values between the creating simulation and the NIU at the creating simulation node varied from 10 milliseconds to over one second. (The collected data were used to support the latency test objective, Test Objective 3.)

- The simulation computer at the SIMLAB overheated and quit. The cause of the overheating appeared to be the floodlights attached to the ceiling for videotaping.

3.3 Parametric Study Mission

3.3.1 Parametric Study Mission Plan

Because of the lofting problem experienced during the V&V Mission, some of the trials in the Parametric Study Mission had to be devoted to V&V activity. These runs followed the manual runs for the V&V Mission test matrix (Day 1 runs in Table 2.4.2.1-1). Additional runs were to follow a subset of the original Parametric Study test matrix (Table 2.4.2.2-1). The original test matrix contained ten trials for each parametric case (profiles P1-P8 in Table 2.4.2.2-1), 5 manual,

and 5 automatic over two days (80 runs total). The test matrix was modified to 40 manual runs, and a single day, because of the problem with automated runs cited earlier. The modified test matrix is given in Table 3.3.1-1. There were to have been 20 runs of the base case V&V flare profile (P2) and 4 sets of 5 runs as follows: one set of the base case V&V non-flare profile (P1), two sets with automatic flare dispense at +0 and +4 seconds warning cue delay (P3 and P5), and one set with automatic flare dispense at +4 seconds and a 7g turn vice the 3.6g turn used in all other trial sets (P8). Test control was exercised from the TCAC at Albuquerque.

Table 3.3.1-1. Modified Parametric Study Mission Test Matrix

Profile/ Repetitions	VARIABLE PARAMETER								REMARKS
	Flare Dispense Time				Target Maneuver Time				
	N/C	+0 s	+2 s	+4 s	N/C	+0 s	+2 s	+4 s	
P1/5					X				Baseline verification profile (V1) No flares
P2/20	X				X				Baseline validation profile (V2) No warning cue
P3/5		X			X				Automatic flare dispense Warning cue at +0 sec
P5/5				X	X				Automatic flare dispense Warning cue at +4 sec
P8/5				X				X	Automatic flare dispense Maneuver: increase turn to 7+ g Warning cue at +4 sec

Note: N/C = no change from baseline (V&V) profile

3.3.2 Parametric Study Mission Results

The Parametric Study Mission was performed on 19 November 1996. Only 26 trials were attempted versus the 40 in the modified plan, largely because the AIM-9 HWIL missile went down for about an hour. Profiles identical to the non-flare and flare V&V profiles (P1 and P2 in Table 3.3.1-1), with no launch warning cues, were used for 25 of the runs. Thus, these trials served to support the V&V test objective. Of 5 manual non-flare trials, 3 were complete, and 2 were in the box. Of 20 manual flare trials, 6 were complete, and all 6 were in the box. One additional trial, a parametric trial with a warning cue at launch (P3), was attempted, but not completed. The in-the-box success rate was only 31%.

Reasons for not completing, or aborting, the runs included: no target PDUs, lack of pilot control of the WSIC, WSIC and WSSF not running, hung missile, SIMLAB NIU failure, SIMLAB not properly reset for run, no lock on target, and no shoot cue.

3.3.3 Parametric Study Mission Conclusions

- Sufficient data for V&V were obtained. The missile lofting problem was fixed, and only a single complete run "in the box" was required for validation of the missile simulation.
  - -- The lofting problem appeared to be caused by a sign err or on the vertical velocity component of the shooter simulation which led the HWIL missile to believe the shooter was climbing, when it was actually descending.

- The target "latitude divergence" was still evident, but was significantly reduced from the V&V Mission. The reduction appeared to be due to correcting the SIMLAB conversion between its internal inertial coordinates (local tangent plane) and geodetic coordinates (latitude, longitude, altitude) and to increasing the iteration rate of the target entity state PDUs at the WSIC NIU (40 Hz versus 20 Hz).

- Failure of the AIM-9 seeker at the SIMLAB resulted in extended downtime and prevented the accomplishment of the entire Parametric Mission test matrix.

- Latency magnitudes and variability were both significantly reduced in this set of trials, to 30-60 milliseconds between the originating simulation and the NIU at the receiving node, apparently because the NIUs were reset before each run. Data from this mission were also used to accomplish Test Objective 3.

- Linking tends to highlight areas of simulation/simulator performance which are incorrect.

- Although limited data were gathered to support the originally intended parametric studies, the trial data, in total, suggests the ADS architecture has utility for parametric studies.

3.4 Latency Study Mission:

Originally, the test team envisaged a series of trials where latency would be treated as a controlled variable, and the sensitivity of measures of interest to latency values could be quantitatively explored (Table 2.4.2.3-1). Because of a combination of schedule slips, and an abundance of latency data collected in the missions already performed, the Latency Study Mission was judged to be redundant, and it was canceled.

4.0 Analysis of Test Objectives

4.1 Test Objective 1: Assess the validity of AIM-9 data obtained in the LSP ADS configuration

This objective involves both verification and validation of the LSP results. Verification is the process of determining that a simulation accurately represents the developers ' conceptual description and specifications. Validation is the process of determining the extent to which the simulation accurately represents the real world from the perspective of the intended uses.

4.1.1 Verification

The WSSF, WSIC, and SIMLAB have been previously verified for their intended uses. Therefore, the LSP verification is to confirm that the simulation (i.e., the three linked simulators) operates as designed when the simulators are real-time linked through an ADS network and can be used to replicate an actual live fire test, including the necessary data collection. The verification analysis also determined the fidelity of entity state data transfer between the simulation nodes.

4.1.1.1 Verification Test Method

Data for verification were collected during integration testing and dry runs, in addition to data from executing the missions.

The qualitative verification involved demonstrating that the simulators are properly linked by their behavior during integration testing and dry runs, as well as the actual missions. During the missions, the first several passes (5-10) were used for verification and used the basic live fire profile, but without flare countermeasures (verification passes were designated as Profile V1). Successful qualitative verification resulted if the LSP inputs were demonstrated to correctly drive each simulator - i.e. the F/A-18 WSSF acquired and tracked the F-14 WSIC; the WSSF provided the proper prelaunch inputs to the AIM-9 SIMLAB and launched the missile; the SIMLAB responded to the WSSF prelaunch and launch initiate inputs; the SIMLAB acquired and tracked the WSIC; and the WSIC acted as the target.

The quantitative verification involved checking the flow of entity state data between the simulation nodes during the actual missions. Where possible, data were collected at four check points as they were created by one simulator, processed, transmitted to, and received by another simulator. Figure 4.1.1.1-1 shows the generic data acquisition points. The output of the originating simulator "A" (i.e., its generated, "raw" data) was recorded at (1), the originating simulation computer. The PDU output of the NIU at the originating simulation facility was recorded at (2), the PDU logger in the originating facility. The PDUs received at the NIU at the receiving simulation facility was recorded at (3), the PDU logger in the receiving facility. Finally, the data input to the receiving simulator "B" was recorded at (4), the receiving simulation computer.

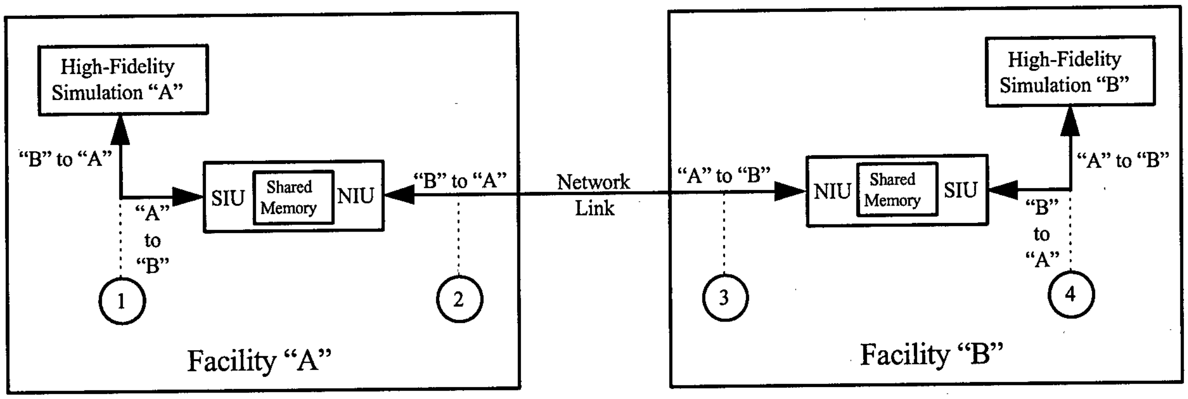


Figure 4.1.1.1-1. Data Collection for Quantitative Verification

4.1.1.2 Verification Analysis Method

The qualitative verification analyses involved verifying the following:

- The WSSF and WSIC executed their respective profiles and achieved the desired shot box parameters given in Table 4.1.1.2-1. This was determined from the quick-look readout of the launch conditions in the SIMLAB.

Table 4.1.1.2-1. Shot Box for LSP Trials

Parameter	Acceptable Range (Relative to LPN-15 Value)
Velocity of Each Aircraft at Launch	±50 ft/s
Altitude of Each Aircraft at Launch	±500 ft
Launch Range	±1500 ft
Shooter Lead Angle	±5°
Target Aspect at Launch	±10°

- The WSSF launched the missile in the SIMLAB. This occurred when trigger squeeze by the WSSF pilot resulted in initiation of the SIMLAB missile HWIL simulation.
- The missile in the SIMLAB responded to the target during its flyout:
  -- The missile seeker tracked the target, as determined by AIM-9 expert monitoring the seeker telemetry (TM) channels.
- Quick-look missile TM channels in SIMLAB were operating properly. This was verified by the SIMLAB operators.
- All data recording systems were operating properly. This was verified by reports from each facility.

The quantitative verification involved analysis of the entity state data (position, velocity, and orientation of entity) as follows:

- For each pair of simulators, data collected at points (1) and (2) in Figure 4.1.1.1-1 were compared to determine if the conversion of high-fidelity simulation output to PDUs occurred correctly (format and accuracy). The entity state data undergo a reference frame transformation when PDUs are created, so that the entity state data elements could not be directly compared. Instead, the appropriate transformations were applied independently to the PDU data before comparing the simulation output. Differences between the transformed PDU data elements and the simulation output were computed. Non-zero differences were noted, but were partly due to errors in independently transforming the PDU data for the comparison.

- Data collected at points (2) and (3) in Figure 4.1.1.1-1 were compared to determine if the data were properly transmitted between facilities. This was a direct comparison between PDU data elements collected at each facility. Differences between the data elements of the PDUs were computed. Non-zero differences were attributed to errors in the transmission process (ADS-induced errors).

- Data collected at points (3) and (4) in Figure 4.1.1.1-1 were compared to determine if the conversion of PDUs to high-fidelity simulation input occurred correctly. As above, the appropriate transformations were applied independently to the PDU data before comparing the simulation output. Differences between the transformed PDU data elements and the simulation input are computed. Non-zero differences were noted, but were partly due to errors in independently transforming the PDU data for the comparison.

- Data collected at points (1) and (4) in Figure 4.1.1.1-1 we re directly compared to determine the net effect on data transfer between simulation nodes.

- The comparison was done by matching data recorded at each pair of facilities for each data element (e.g., the latitude position of an entity generated at one facility was received by another facility).

Static Verification. The direct matching of entity state data was done by "freezing" the entity in the originating simulation so that the same set of data was repeatedly created and transmitted to the other facilities. This was necessary because the positional data out of or into the simulations was dead reckoned at the NIUs during dynamic operation, preventing a direct comparison. The full four-point comparison (Fig. 4.1.1.1-1) could only be performed for data exchanged between the target (F-14 WSIC) and the shooter (F/A-18 WSSF).

The four-point comparison did not work for the shooter or target data sent to the SIMLAB. The SIMLAB only logs raw data when the AIM-9 simulation is actually running (during missile flyout). As a result, the raw shooter and target data produced when the WSSF and WSIC were "frozen" were not logged at the SIMLAB and could not be used in the verification process.

Dynamic Verification. The verification methodology outlined in the LSP TAP needed revision in order to verify the target data being transmitted to the SIMLAB during the missile flyout. Since the target position was changing with time during the flyout, a dynamic (F-14 simulator "flying),

rather than static (F-14 simulator "frozen"), comparison was needed. This was attempted by comparing the time histories of the target latitude, longitude, altitude derived from (1) raw data logged in the WSIC simulation, (2) PDUs logged at the WSIC, (3) PDUs logged at the SIMLAB, and (4) raw data logged in the SIMLAB simulation. It was hoped that the time histories would all have the same shape, and simply be displaced in time due to latency between the logging locations. However, there were problems in directly comparing the time histories:

- The raw data logged in the WSIC simulation were not logged during the actual LSP runs, but by replaying the WSIC simulation later and sampling the data. As a result, the sampled data points represented different times than those from the PDUs logged at the WSIC (see Fig. 4.1.1.2-1). This prevented a direct comparison between (1) and (2) above. Instead, the static results were used to estimate the accuracy of transforming the raw WSIC simulation data into PDUs, and the PDUs created at the WSIC NIU were assumed to represent the raw simulation output, within the accuracy of the static results.

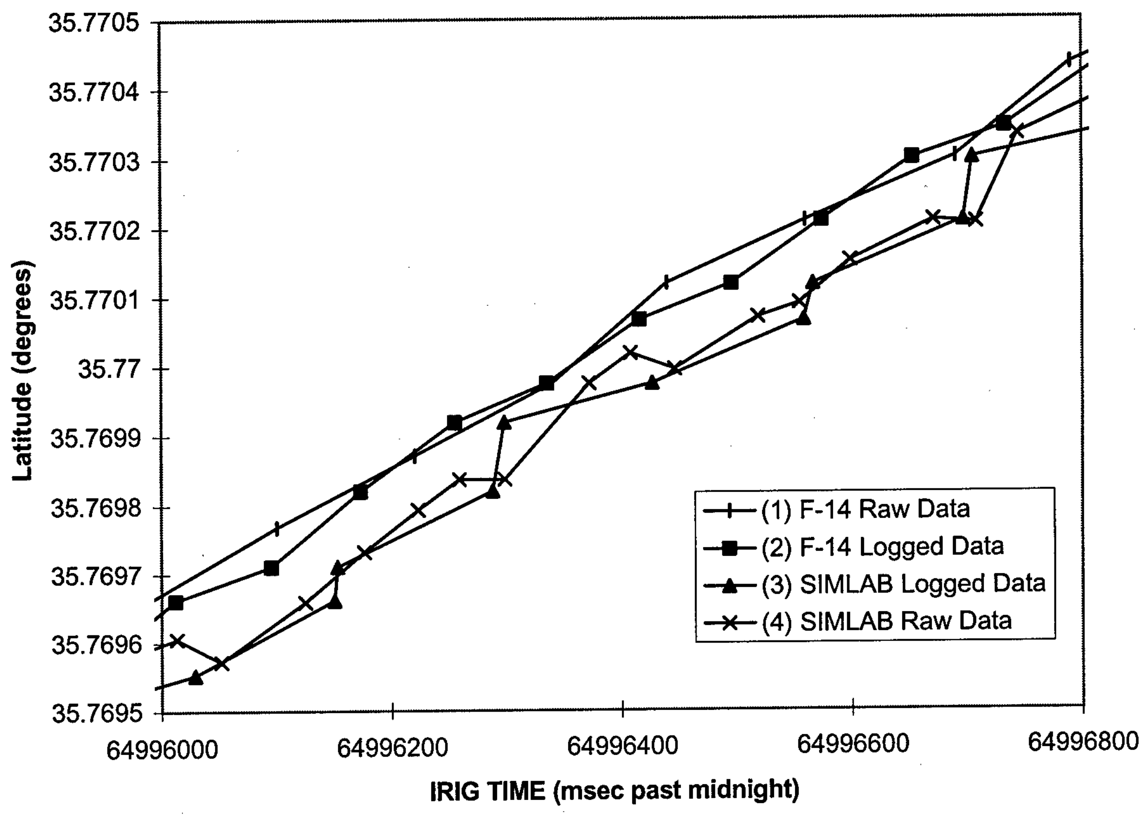


Figure 4.1.1.2-1. Target Latitude vs. Time During Run #23 (10/29/96)

- When the target PDU data logged at the SIMLAB (according to log time) were compared to the PDU data logged at the WSIC (according to PDU, or creation, time), the result was a target trajectory curve in which the individual data points were "misaligned" in time (see Fig. 4.1.1.2-1). In other words, the trajectory curve went from smooth in shape at the WSIC to "unsmoothed" in shape at the SIMLAB. This was caused by variations in the

WSIC-to-SIMLAB latency and prevented a direct comparison between (2) and (3) above. If the latency had been constant, the SIMLAB trajectory would have had the same shape as the WSIC trajectory, but delayed in time by a fixed amount (the latency value).

- The raw target data logged in the SIMLAB simulation corresponded to different times than that from the PDU data logged at the SIMLAB (see Fig. 4.1.1.2-1). Note that the data were read into the SIMLAB simulation at a higher rate than the logged PDU data and that dead reckoning was used. This prevented a direct comparison between (3) and (4) above.

The result of these problems was that the verification methodology outlined in the LSP TAP had to be modified as follows:

- As Figure 4.1.1.2-1 shows, latency affected the transfer of dynamic entity state data from the WSIC to the SIMLAB. In order to quantify the effect on data validity, the latency between the WSIC and SIMLAB simulations was analyzed to determine the mean and standard deviation values.
  -- The latency was computed as follows:
    --- The target's north component of velocity from a target entity state PDU was matched to that from a SIMLAB raw simulation frame. Due to the target's motion, this component of velocity exhibited the most change between frames (i.e., the maximum target acceleration is in the north direction during the engagement) and could be most readily matched. The NIUs did not dead reckon velocity, so that a direct comparison was possible.
    --- The latency was computed from the difference in the SIMLAB frame time (determined by the IRIG times for the frames) and the PDU time (which gives the time that the data were created in the WSIC simulation).
  -- The standard deviation represented a random component of the latency and resulted in a variation in the time that the target entity state data were received at the SIMLAB. Since the SIMLAB simulation ran asynchronously and in real-time, these time variations resulted in position variations, or uncertainties, in the simulation (data were fed into the simulation as they were received, without reference to their creation time).

- The standard deviation of the latency was used to estimate the uncertainty in the target location perceived at the SIMLAB compared to the value generated by the WSIC. The uncertainty in the target position due to the random latency variations was estimated by multiplying the standard deviation of the latency by the target velocity:

$$\delta x = v \ \delta t \qquad (1)$$

where δx = uncertainty in target position
v = target velocity
δt = standard deviation of the WSIC-SIMLAB latency

4.1.1.3 Verification Results

Qualitative verification before the Mission Rehearsal indicated that:

- The shooter was tracking the target.
- The shooter was initializing and launching the missile.
  -- The HUD display in the SIMLAB replicated the HUD display in the WSSF.
- The missile was tracking and intercepting the target.

Verification of F/A-18 Data Between WSSF and WSIC . The F/A-18 entity state data were checked according to the four-point comparison illustrated in Figure 4.1.1.1-1 when the WSSF simulation was "frozen" (static verification). The results for positional data are given in Table 4.1.1.3-1 which gives the differences (deltas) in latitude, longitude, and altitude from each previous logging location (latitude and longitude differences were directly measured and converted into distances in the table). Note that the actual PDU data were not in the form of latitude, longitude, and altitude and had to be converted into this form for the comparison. The conversion was done using TCAC algorithms.

Table 4.1.1.3-1. Verification of Shooter Positional Data Passed From WSSF to WSIC

Location	Latitude	Longitude	Altitude	Delta Lat (deg)	Delta Lat (ft)	Delta Lon (deg)	Delta Lon (ft)	Delta Alt (ft)
WSSF raw	35.70416638	-117.6888887	11700.00					
WSSF logger	35.70416583	-117.6888842	11699.45	-5.5E-07	-0.201	4.5E-06	1.335	-0.55
WSIC logger	35.70416583	-117.6888842	11699.45	0	0	0	0	0
WSIC raw	35.70416600	-117.6888810	11699.41	1.7E-07	0.062	3.2E-06	0.95	-0.037
Net Deltas				-3.8E-07	-0.139	7.7E-06	2.285	-0.587
Total of Net Deltas (ft)	2.36							

The shooter velocity components (north, east, down) and orientation components (roll, pitch, yaw) were also checked according to the four-point comparison. These were all found to agree with each other within the precision of the raw data readout.

The conclusions are:

- The positions from the PDUs agreed with the WSSF raw data to within 1.5 ft (root-sum-square (RSS) of the deltas from the second row of Table 4.1.13-1). This reflected the accuracy of the TCAC algorithms for converting the PDU coordinates into latitude, longitude, and altitude, as well as the accuracy of the lab frame-to-PDU frame conversion.
- The PDU data were not changed during transmission from the WSSF to the WSIC.
- The total net accuracy for transmitting target positional data from the WSSF to the WSI C (via PDUs) is about 2.4 ft (the total was obtained from the RSS of the individual nets), and was acceptable for the LSP scenario. Note that the comparison of raw simulation data were direct and did not require coordinate transformations.

- The shooter velocity and orientation data were not changed significantly during transmission from the WSSF simulation to the WSIC simulation (values agreed within the precision of the raw data readout).

Verification of F-14 Data Between WSIC and WSSF. The F-14 entity state data were checked according to the four-point comparison illustrated in Figure 4.1.1.1-1, and results are given in Table 4.1.1.3-2 (latitude and longitude differences were directly measured and converted into distances in the table). As above, the actual PDU data were converted into latitude, longitude, and altitude for the comparison.

Table 4.1.1.3-2. Verification of Target Positional Data Passed From WSIC to WSSF

Location	Latitude	Longitude	Altitude	Delta Lat (deg)	Delta Lat (ft)	Delta Lon (deg)	Delta Lon (ft)	Delta Alt (ft)
WSIC raw	35.727818	-117.697784	10392.5					
WSIC logger	35.72781809	-117.6977811	10392.17	9E-08	0.033	2.9E-06	0.860	-0.328
WSSF logger	35.72781809	-117.6977811	10392.17	0	0	0	0	0
WSSF raw	35.72781808	-117.6977787	10393.1	-1E-08	-0.004	2.4E-06	0.712	0.928
Net Deltas				8E-08	0.029	5.3E-06	1.572	0.6
Total of Net Deltas (ft)	1.68							

The target velocity components (north, east, down) and orientation components (roll, pitch, yaw) were also checked according to the four-point comparison. These were all found to agree with each other within the precision of the raw data readout.

The conclusions are:

- The positions from the PDUs agree with the WSIC raw data to within 1 ft (RSS of deltas from second row of Table 4.1.1.3-2). This reflects the accuracy of the TCAC algorithms for converting the PDU coordinates into latitude, longitude, altitude, as well as the accuracy of the lab frame-to-PDU frame conversion.
- The PDU data were not modified during transmission from the WSIC to the WSSF.
- The total net accuracy for transmitting target positional data from the WSIC to the WSSF (via PDUs) is about 1.6 ft (the total was obtained from the RSS of the individual nets), and was acceptable for the LSP scenario.
- The target velocity and orientation data were not changed significantly during transmission from the WSIC raw simulation to the WSSF raw simulation (values agreed within the precision of the raw data readout).
- Comparing Table 4.1.1.3-2 with Table 4.1. 1.3-1 shows smaller net differences for the target latitude and longitude. The reason for these smaller differences is not known.

Verification of F/A-18 Data Between WSSF and SIMLAB. The SIMLAB only logs raw data when the AIM-9 simulation is actually running (during missile flyout). As a result, the raw shooter (F/A-18 WSSF) data produced when the WSSF was "frozen" were not logged at the SIMLAB and could not be used in the verification process. Instead, the results of the verification of the shooter data between the WSSF and the WSIC (Table 4.1.1.3-1) were assumed to also apply to the transfer between the WSSF and the SIMLAB. Also, the launch conditions determined at both the WSSF and at the SIMLAB were compared and were found to agree within acceptable tolerances (see results for Test Objective 3 below). Note that the only shooter entity state data used by the SIMLAB missile simulation were the shooter initial conditions.

Verification of PDU Data Between All Nodes. Spot checks were performed on the PDUs for all three entities by comparing entity state values for the same PDU time from PDUs logged at different nodes. In all cases, the entity state data matched perfectly.

Verification of F-14 Data Between WSIC and SIMLAB. As noted for the F/A-18 data, the raw target (F-14 WSIC) data produced when the WSIC was "frozen" were not logged at the SIMLAB and could not be used in the verification process. Instead, the raw data produced at the WSIC could only be compared to PDU data logged at the SIMLAB. The F-14 PDUs logged at the SIMLAB exactly matched those logged at the WSIC, so that the results for the WSIC/WSSF comparison apply:

- The positions from the PDUs agreed with the WSIC raw data to within 1 ft.
- The PDU data were not modified during transmission from the WSIC to the SIMLAB.

The target data being transmitted to the SIMLAB during the missile flyout was verified by applying the dynamic verification process outlined in Section 4.1.1.2. Equation 1 was used to estimate the uncertainty in the target position data input into the SIMLAB simulation. Data from the Parametric Study Mission runs (11/19/96) were used, because these runs exhibited the smallest latencies of any mission. Results are given in Table 4.1.1.3-3.

Table 4.1.1.3-3. Uncertainty in Target Position Input into SIMLAB Simulation

Run # (11/19/96)	Total Latency (ms)		Target Velocity (ft/s)	Target Position Input Uncertainty (ft)
	Mean	Std Dev		
9	70.3	46.3	772.04	35.7
10	54.0	30.3	783.43	23.7
12	76.0	36.7	781.22	28.7
18	71.4	51.8	783.31	40.6
19	83.8	49.0	785.14	38.5
22	64.6	32.9	774.41	25.5
Mean	70.0	41.2	779.93	32.1

- Note that the standard deviations of the WSIC-to-SIMLAB latencies were significant (up to 73% of mean value).

- The standard deviation resulted in a random variation in the target position which cannot be compensated for in real-time. Rather, this represents an uncertainty in the target location input to the SIMLAB simulation, analogous to measurement error in range TSPI systems.

The SIMLAB simulation for the missile flyout is a "rate-driven" simulation. This means that it uses the target velocity as an input driver and integrates the velocity to determine the target location as an output. When the target latitude, longitude, and altitude computed by the simulation were compared to the target latitude, longitude, and altitude input into the simulation, significant differences were found.

- The differences were largest in the target latitude and were found to increase monotonically with time, leading to a "latitude divergence" which was largest at the end of the missile flyout.
- This problem first became evident during the V&V Mission, and the latitude divergences observed corresponded to disagreements of 200-300 ft between the WSIC-determined and SIMLAB-computed positions at the end of the missile flyout.
- The magnitude of the disagreement was reduced by increasing the target PDU update rate from 12.5 Hz to 20 Hz for the Parametric Study Mission. As a result, the latitude divergences corresponded to disagreements of less than 50 ft for this mission. An example is given in Figure 4.1.1.3-1. (Note the "jagged" features in the solid curve of Fig. 4.1.1.3-1. These features are like those of curve (4) in Fig. 4.1.1.2-1 and correspond to the uncertainty in the target latitude due to WSIC-to-SIMLAB latency variations).
- The total divergence between the target position input into the SIMLAB simulation and the target position computed by the SIMLAB simulation was quantified as follows:
  - -- The difference betwe en the target latitudes was computed. Because of the uncertainty in the target latitude input into the SIMLAB simulation (Table 4.1.1.3-3), the difference also had an uncertainty. To minimize this uncertainty, the last ten values of the difference in latitudes were averaged, and the standard deviation of these was used to estimate the uncertainty in the mean difference.
  - -- The differences between the target longitudes and altitudes were also computed. These varied randomly over the entire time of the missile flyout, so that all values of these differences were averaged.
  - -- The mean values of the differences in the latitude, longitude, and altitude were combined for a net position divergence for each run (given by the RSS of the individual latitude, longitude, and altitude differences). The uncertainty in the net value was estimated by the RSS combination of the standard deviations. Results are in Table 4.1.1.3-4. Note that the mean net position difference (36.0 ft) is comparable to the mean position uncertainty from Table 4.1.1.3-3 (32.1 ft).

Table 4.1.1.3-4. Difference in Target Position Computed by SIMLAB Simulation and Target Position Input Into SIMLAB Simulation

Run # (11/19/96)	Latitude Difference (ft)	Longitude Difference (ft)	Altitude Difference (ft)	Net Position Difference (ft)
9	28.5 ± 2.9	-11.7 ± 9.3	6.7 ± 5.6	31.5 ± 11.2
10	37.2 ± 2.7	-5.7 ±11.4	5.9 ± 5.7	38.1 ± 13.0
12	39.0 ± 2.7	7.0 ± 13.3	-11.0 ± 5.5	41.1 ± 14.6
18	29.7 ± 1.7	-15.0 ± 17.4	6.4 ± 6.4	33.9 ± 18.6
19	15.3 ± 1.1	-36.7 ± 20.6	8.2 ± 6.4	40.6 ± 21.6
22	27.2 ± 2.1	-13.5 ± 10.8	4.8 ± 5.5	30.7 ± 12.3
Mean	29.5 ± 2.2	12.6 ± 13.8	3.5 ± 5.9	36.0 ± 15.2

The major source of the latitude divergence appeared to be velocity integration errors in the SIMLAB simulation. (Recall that the simulation integrated the target velocity to determine the target position.)

- The simulation assumed that each velocity component of the target remained constant over each integration period (the integration period is the frame time of the simulation). This assumption was utilized because the integration must be performed in real-time, without knowledge of how the velocity will change during the integration time.

- Since the target was executing a constant velocity turn, the velocity components were actually changing with time, so that the SIMLAB assumption of constant velocity was not valid. The source of the integration error is illustrated in Figure 4.1.1.3-2.

- The magnitude of the integration error was estimated by using the initial and fina l target velocities for each integration step to compute the triangular integration error area illustrated in Figure 4.1.1.3-2, according to:

$$\delta v = \sum \frac{1}{2}(v_f - v_i)\Delta t \qquad (2)$$

where δv = velocity integration error
v_f = velocity at the end of the integration time step
v_i = velocity at the start of the integration time step
Δt = size of each integration time step
Σ indicates the sum of the terms over all integration time steps

- Results of applying Equation 2 are given in Table 4.1.1.3-5. T his table also compares the integration error estimates to the net target position differences from Table 4.1.1.3-4.

Table 4.1.1.3-5. SIMLAB Velocity Integration Error Estimates

Run # (11/19/96)	Integration Error Estimate (ft)	Net Position Difference (ft)
9	24.7	31.5 ± 11.2
10	30.0	38.1 ± 13.0
12	29.7	41.1 ± 14.6
18	35.5	33.9 ± 18.6
19	31.4	40.6 ± 21.6
22	24.8	30.7 ± 12.3
Mean	29.4	36.0 ± 15.2

Conclusions from Table 4.1.1.3-5 are as follows:

- The integration error estimate accounts for most, but not all, of the position divergence.
  -- In addition to assuming that the velocity was constant over each integration step, it was also noted that frequently the target velocity components input into the SIMLAB simulation were not being updated at the PDU update rate set on the NIUs (as low as ~3 Hz for the velocity updates vs. 20 Hz for the PDU update rate). The target latitude was computed by integration of the north velocity component, and this component decreased with time during the target's constant speed turn. Hence, when the velocity components were not updated, the simulation used too large of a value for the north velocity component, and this aggravated the integration error.
- The total mean target position error (36 ft) is much larger than the raw data-to-PDU transform error (~1-2 ft), and the uncertainty in the error is significant (~40% of the mean value).
- The total mean target position error is also significantly larger than the missile lethal radius. This means that lethality results based on the SIMLAB simulation-computed miss distances and on PDU-computed miss distances can disagree on whether or not the missile killed the target. Because the target representation in the SIMLAB simulation does not accurately represent the actual target behavior, the SIMLAB value of miss distance cannot be considered the "correct" value (even though the missile behavior may be accurate for the representation of the target presented to it in the SIMLAB).

CONCLUSION. The target representation in the SIMLAB simulation does not accurately reflect the target motion generated at the WSIC. Unless this problem can be solved, the LSP configuration cannot be used for closed-loop applications in which the missile and the target respond to each other in real-time. A possible solution would be improving the SIMLAB integration of target velocity to determine position by using the target acceleration at the start of each integration step to partially correct for the change in velocity during the step. Also, the target velocity component values input into the SIMLAB simulation need to be updated at the same rate as the other entity state data.

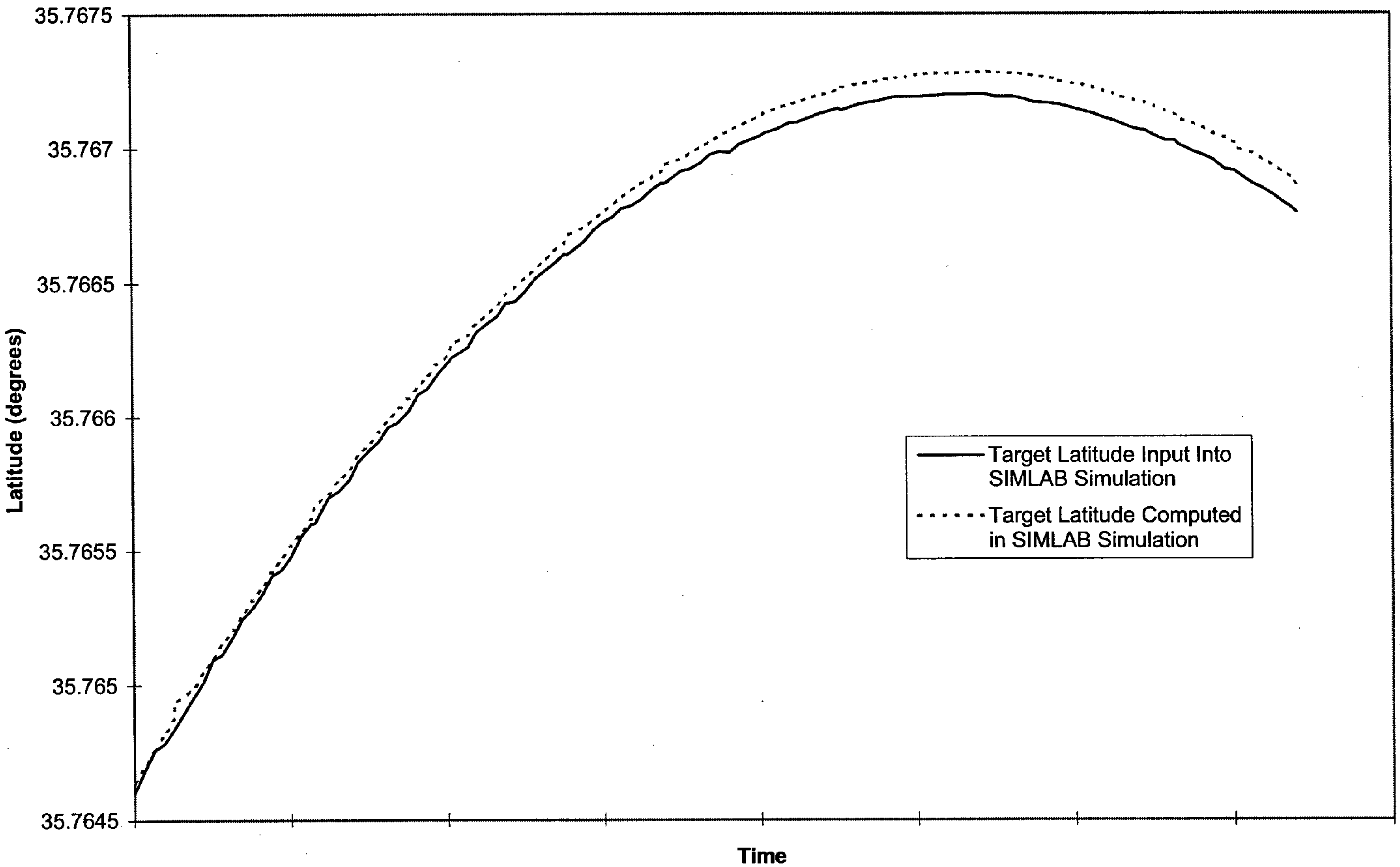
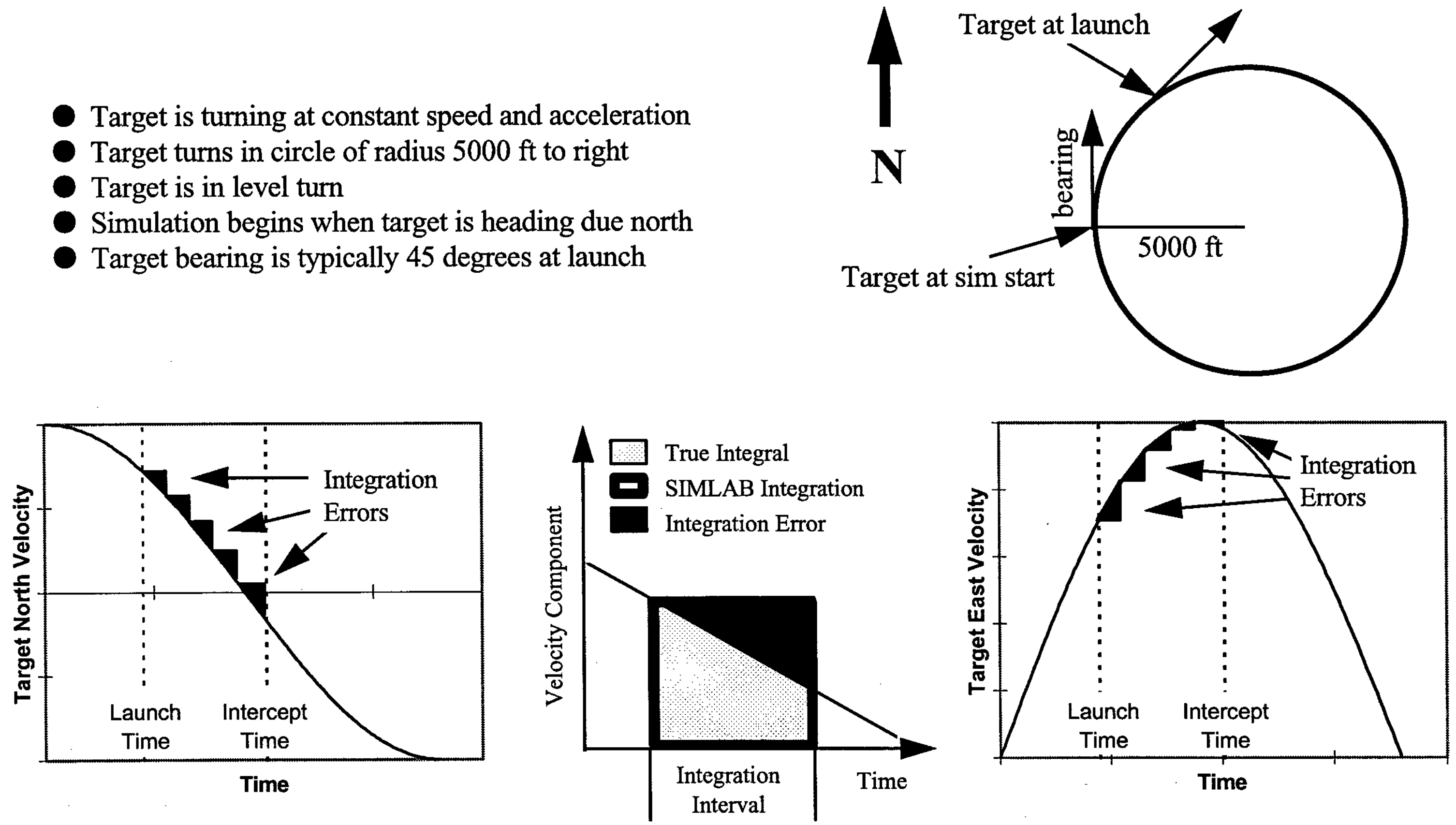


Figure 4.1.1.3-1. Latitude Divergence of Target Trajectory in Run #12 (11/19/96)

- Target is turning at constant speed and acceleration
- Target turns in circle of radius 5000 ft to right
- Target is in level turn
- Simulation begins when target is heading due north
- Target bearing is typically 45 degrees at launch



- SIMLAB simulation integrates target velocity components over time to determine target position
- Errors result because the simulation assumes the velocity component stays constant during each integration interval
- The true integral is the area under the target velocity component vs. time curves
- The dark triangular areas illustrate the integration error for each integration time interval
- Note that integration of the north velocity component to get north position gives a larger error than the east component

Figure 4.1.1.3-2. Illustration of Velocity Integration Error in SIMLAB Simulation

Verification of AIM-9 Flyout Data . The missile entity state data were checked according to the four-point comparison illustrated in Figure 4.1.1.1-1. The latitude, longitude, and altitude generated at the end of the missile flyout were used to eliminate dead reckoning adjustments to the PDU values, and results are given in Table 4.1.1.3-6 (latitude and longitude differences were directly measured and converted into distances in the table). As before, the actual PDU data were converted into latitude, longitude, and altitude for the comparison.

Table 4.1.1.3-6. Verification of Missile Positional Data Passed From SIMLAB to WSSF (from Run #9 on 11/19/96)

Location	Latitude	Longitude	Altitude	Delta Lat (deg)	Delta Lat (ft)	Delta Lon (deg)	Delta Lon (ft)	Delta Alt
SIMLAB raw	35.76203053	-117.6784207	10292.3					
SIMLAB logger	35.76203378	-117.6784249	10291	3.25E-06	1.188	-4.2E-06	-1.245	-1.3
WSSF logger	35.76203378	-117.6784249	10291	0	0	0	0	0
WSSF raw	35.76203397	-117.6784219	10292.3	1.9E-07	0.069	3E-06	0.889	1.3
Net of Deltas				3.44E-06	1.257	-1.2E-06	-0.356	0
Total of Nets	1.31							

The conclusions are:

- The positions from the PDUs agreed with the SIMLAB raw data to within 2 .2 ft (RSS of deltas from second row of Table 4.1.1.3-6). This reflected the accuracy of the TCAC algorithms for converting the PDU coordinates into latitude, longitude, altitude, as well as the accuracy of the lab frame-to-PDU frame conversion.
- The PDU data were not changed during transmission from the SIMLAB to the WSSF.
- The net accuracy for transmitting target positional data from the SIMLAB to the WSSF (via PDUs) is about 1.3 ft (the total was obtained from the RSS of the individual nets), and is acceptable for the LSP scenario. Note that the comparison of raw simulation data were direct and did not require coordinate transformations.

However, a problem was found with the missile flyout when the SIMLAB inertial reference frame data was compared to latitude, longitude, and altitude:

- The SIMLAB simulation transformed the incoming latitude, longitude, and altitude of the shooter and target into its own reference frame:
  - -- The horizontal component of the target velocity vector (referred to as targe t bearing) defined an x-axis in the horizontal plane. The origin was the x-component of the launch location.
  - -- The z-axis was also in the horizontal plane and perpendicular to the x-axis. The origin was the z-component of the launch location.
  - -- The y-axis was in the local vertical direction and the y-component was identical to the entity altitude.

- The missile flyout was computed in the simulation in terms of this x,y,z reference frame.

- When ranges between the missile and the target were computed using the x,y,z coordinates of each and compared to ranges computed using the latitude, longitude, and altitude of each, the initial (launch) range was found to agree very well, but the final range was found to disagree by ~1000 ft.
  - -- The disagreement is illustrated in Figure 4.1.1.3-3 which shows the "God's-eye" view of the missile and target trajectories observed in the SIMLAB reference frame (Fig. 4.1.1.3-3(a)) compared to the trajectories as determined by PDU data (Fig. 4.1.1.3-3(b)).
    - --- For the comparison, the SIMLAB trajectory data were rotated by an angle equal to the target bearing at launch; this rotates the SIMLAB x-axis into the north direction.
    - --- Note that the missile trajectories agree, but not the target trajectories. As a result, the missile guides to the target according to SIMLAB data, but does not according to PDU data.

The problem of the range disagreement was traced to an error in initializing the target location in the x,y,z reference frame.

- Instead of computing the initial target location in the x,z plane by using the target bearing, this was done by incorrectly using the target heading.

- In the LSP scenarios, the angle between the target bearing and heading was typically 5.5 °. This angular difference over the launch range resulted in an offset in the initial x,y,z position of the target of ~1000 ft.

- This initial offset applied to each SIMLAB simulation frame, so that the missile was flying toward a target in the SIMLAB x,y,z reference frame which was always offset from the true target position by ~1000 ft. The range can be corrected by applying the offset to each simulation time step.
  - -- This constant offset value applied to each simulation frame because the simulation used the initial location of the target at launch and then determined the location change in each frame by integrating the target velocity.

- Figure 4.1.1.3-4 shows that by first translating the SIMLAB target data and then rotating the data values, the target trajectory from SIMLAB data overlays the trajectory from PDU data.
  - -- Note that the target trajectories do not exactly overlay, because of the latitude divergence problem.

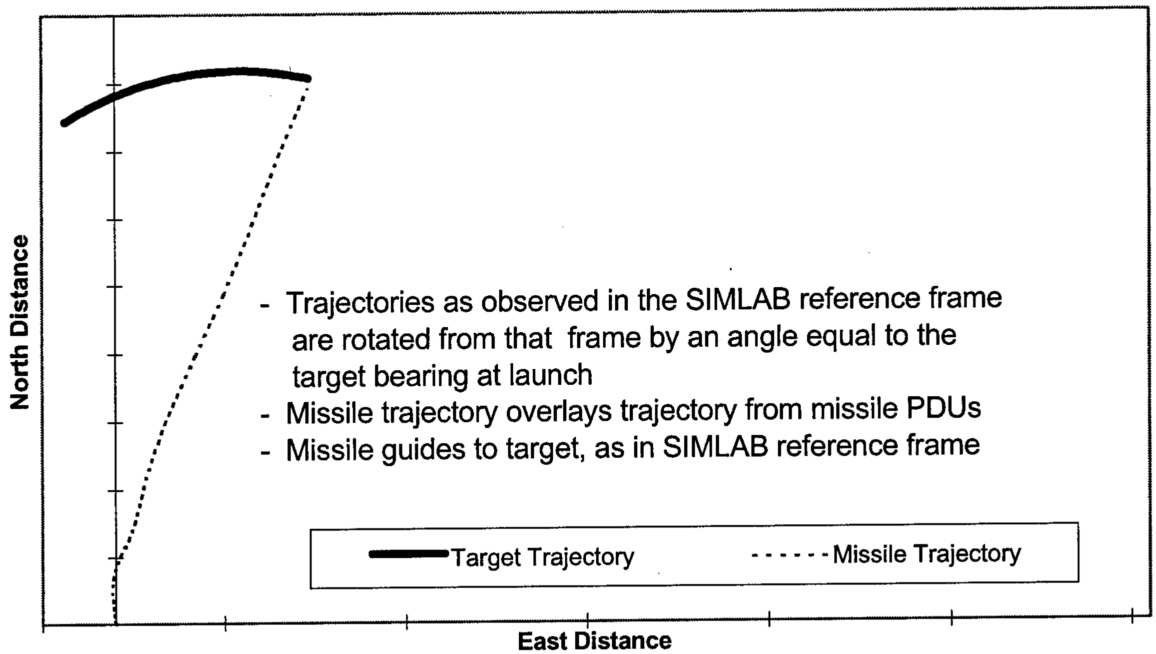


Figure 4.1.1.3-3(a). Missile and Target Trajectories from SIMLAB Data (Run #12 on 11/19/96)

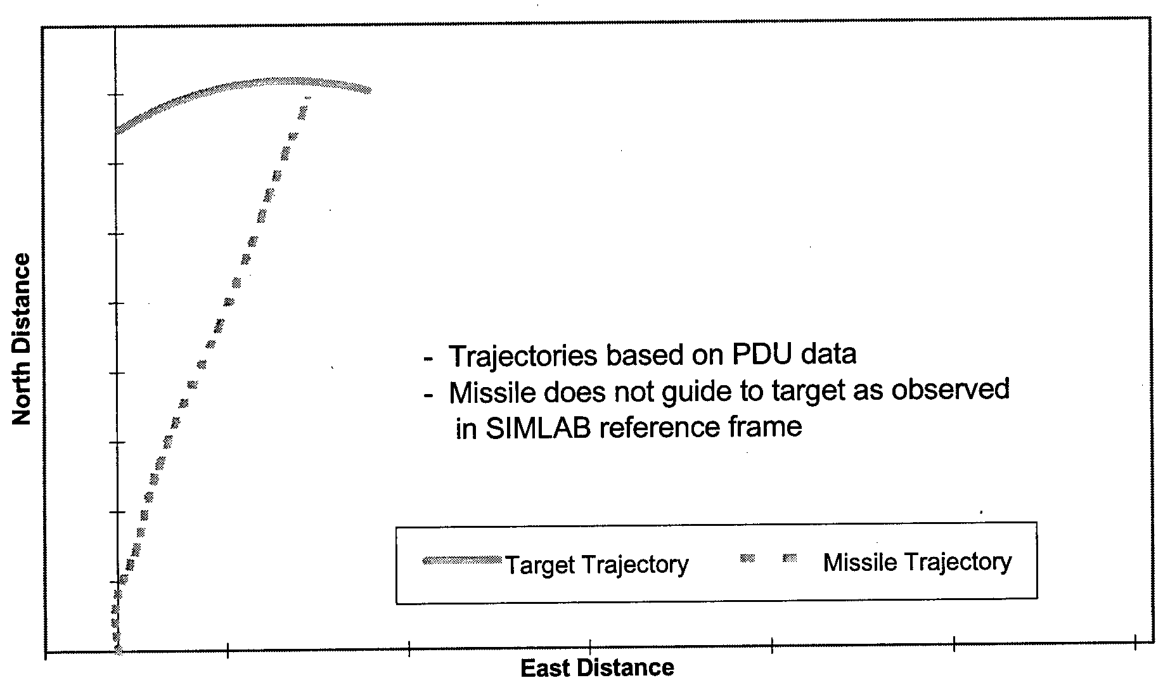


Figure 4.1.1.3-3(b). Missile and Target Trajectories from PDU data (Run #12 on 11/19/96)

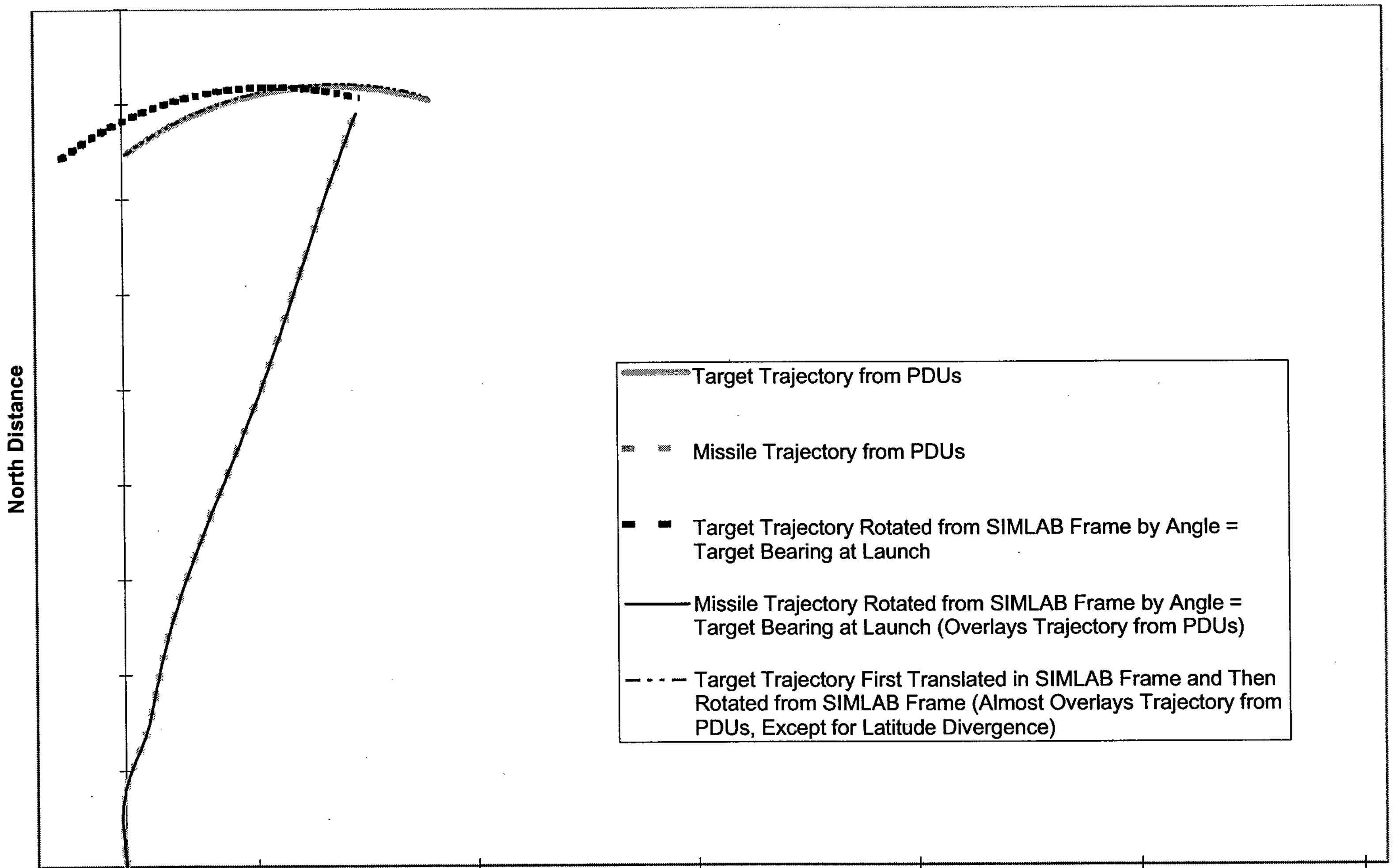


Figure 4.1.1.3-4. Illustration of Correction to Align Target Trajectories From SIMLAB and PDU Data (Run #12 on 11/19/96)

4.1.1.4 Verification Summary

The results for the verification objective are summarized as follows:

- The error in transforming from the raw simulation positional data to entity state PDU data is 1-2 ft.
  -- This is an acceptable value.
- There were no errors in transforming velocity and orientation data.
- No errors were found in transmitted PDU data values. All PDU data passed between nodes matched.
- There were a number of errors in the target positional data, as represented in the SIMLAB simulation.
  -- Random latency variations introduced uncertainty in the targe t position. The random nature of these variations prevents implementing a deterministic real-time correction for all latency effects.
  -- The target latitude determined by the SIMLAB simulation diverged from the WSIC value during the missile flyout. The cause appears to be primarily due to the simplistic method used by the SIMLAB to determine target position by integrating its velocity. A more sophisticated integration technique and higher velocity update rate could significantly reduce the divergence.
  -- The target representation in the SIMLAB simulation coordinate frame was wrong due to an error in the coordinate frame transformation used. This was fixed after the Parametric Study Mission.

4.1.2 Validation

The objective of the validation process is to demonstrate that the performance of the AIM-9M-8/9 in the SIMLAB facility, driven by the linked simulators (the WSSF as the shooter and the WSIC as the target), was consistent with that of an actual AIM-9M-8/9 missile live fire profile under the same conditions.

4.1.2.1 Validation Test Method

Data for validation were collected during the Parametric Study Mission (11/19/96) runs which replicated the live test profile and during various SIMLAB standalone runs.

The AIM-9M-8/9 JIOT&E live fire test selected as the baseline, LPN-15, is depicted in Figure 4.1.2.1-1. The pilots in the WSSF and WSIC flight simulators attempted to replicate the live fire profile by using scripted passes. The replication profile (with flare countermeasures) was designated as Profile V2 and was baselined on the actual shooter and target parameters and event timing in the LPN-15 scenario. The V&V approach involved comparing the performance of the simulated missile (especially its flyout) to that of the real missile to establish the validity of the ADS configuration.

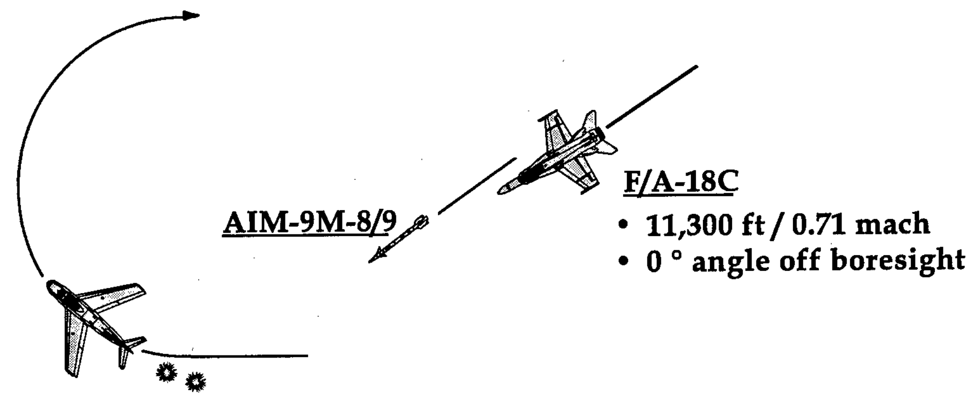


Figure 4.1.2.1-1. AIM-9M-8/9 Live Fire Profile (LPN-15, 9 June 93)

The V2 replication profiles were executed in two basic configurations as follows:

- Manual Linked Runs. The shooter and target simulators were each flown and controlled by pilots. Each aircraft simulator was started manually by local operators when directed by the test controller at the TCAC. Flares were released manually. Each simulator was initialized with pre-established sets of initial conditions that were refined during dry runs so that the two aircraft were able to reliably replicate the LPN-15 launch conditions.

- SIMLAB Standalone Runs. These runs were performed without linking the SIMLAB to the other simulators. They were executed by preprogramming the SIMLAB with the following profiles (including all timed events):
  - -- The baseline LPN-15 profile. These runs are used to verify SIMLAB operation and to provide a baseline for missile flyout results from the linked configuration.
  - -- Launch conditions determined by Monte Carlo sampling of the shooter and target inputs about the LPN-15 profile. The range of conditions which were sampled was the LPN-15 shot box (Table 4.1.1.2-1). These runs are used to develop criteria for initial (i.e., launch) conditions and for the validity of missile flyout results from the linked runs.
  - -- The manual linked run which best replicated LPN-15. These runs were used to determine the run-to-run variations in the SIMLAB output when the shooter and target inputs were held constant (for "best" manual run conditions) and when the ADS network was not used

4.1.2.2 Validation Analysis Method

The SIMLAB was first run in the standalone mode using the LPN-15 live fire test launch conditions and target trajectory as inputs. The purpose was to baseline the SIMLAB missile flyout against the live test data. The SIMLAB was run 20 times using the same LPN-15 inputs each time, because the seeker performance varies slightly run-to-run. The envelope of missile flyouts from the SIMLAB runs was then compared to the LPN-15 data using the quantitative evaluation described below.

Assuming reasonable agreement between the SIMLAB standalone results and the LPN-15 data, the data recorded at the SIMLAB for each run of the validation profile were to be compared to results from the SIMLAB standalone runs. The data used in the comparison were primarily the trajectories of the missile and target. The criteria for determining data matches from the comparisons were to be derived from SIMLAB standalone Monte Carlo runs of the validation profile (V2), as follows:

- The expected range of launch conditions was given by one of the following:
  - -- The exact conditions of LPN-15 (as in the runs for comparison with LPN-15).
  - -- The shot box about the LPN-15 conditions.
  - -- The exact conditions of the manual linked run which best replicated LPN-15.
- The launch conditions and target trajectories were sampled from uniform distributions consistent with the ranges of the values.
- SIMLAB standalone results for missile trajectories were examined to determine the bounding values (see Fig. 4.1.2.2-1).
- The range of SIMLAB standalone results was reviewed to determine if the range represented reasonable comparison criteria.

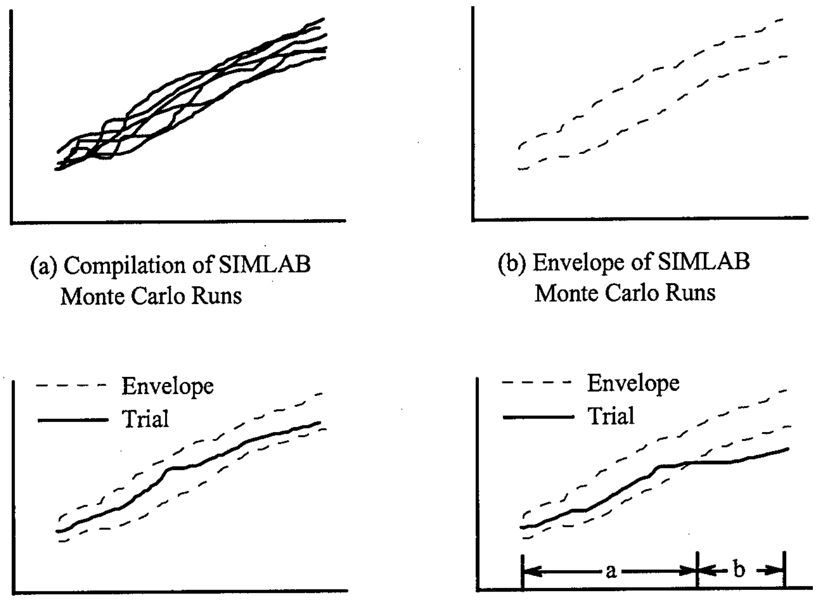
The data recorded in the SIMLAB from the linked missions were compared to the data from one of the three types of SIMLAB standalone runs. The comparison of the missile results was either quantitative (if all SIMLAB inputs were within acceptable ranges) or qualitative (if any SIMLAB input was outside acceptable ranges). The determination of the acceptability of SIMLAB inputs was as follows:

- Initial launch conditions
  - -- Each parameter recorded in the SIMLAB was compared to the shot box.
  - -- If all initial launch parameters were wit hin the shot box, the SIMLAB results were quantitatively evaluated as described below.
  - -- If any initial launch parameter was outside the shot box, the SIMLAB results were qualitatively evaluated as described below.
- Target velocity profile and trajectory
  - -- The target velocity and altitude during the missile flyout were compared to the shot box.
  - -- If both target parameters were within the shot box, the SIMLAB results were quantitatively evaluated as described below.

-- If either target parameter was outs ide the shot box, the SIMLAB results were qualitatively evaluated as described below.
- Target IR intensity
  -- The discrete value for the apparent IR intensity of the target (relative to the flare intensity at the time of first flare deployment) was preset in the SIMLAB (by a combination of IR aperture size and blackbody temperature). This intensity was checked before the linked missions to verify that the value measured in the SIMLAB was within the acceptable range, as determined by the AIM-9 expert.
- Countermeasure parameters
  -- The discrete value for the flare dispense time was compared to the acceptable range of values determined by the AIM-9 expert and was judged to be either acceptable (it was within the acceptable range) or unacceptable (it was outside the acceptable range).
  -- The other flare parameters (dispense rate, temperature, ejection angle) were all preset in the SIMLAB. The value of each of these parameters was checked before the linked missions to verify that the correct value was selected.

The quantitative evaluation of SIMLAB output (used when all SIMLAB inputs were acceptable) was to be as follows:

- Missile trajectory
  -- SIMLAB standalone results for missile trajectories were examined to determine the bounding values, as described above. The steps for doing this with the trajectory data are shown in Figure 4.1.2.2-1 as (a) and (b).
  -- The plot of each parameter recorded in the SIMLAB was compared to the acceptable range of plots determined from the Monte Carlo runs by the AIM-9 expert.
  -- Each parameter was judged to be either acceptable (all points on plot lie within the acceptable range: see Fig. 4.1.2.2-1(c)) or unacceptable (some points on plot lie outside the acceptable range, i.e., those in interval b in Fig. 4.1.2.2-1(d)).
- Missile seeker TM signals
  -- These were analyzed by the AIM-9 expert based on their familiarity with live fire results from many tests. The expert determined if any TM signals appeared to be invalid and what characteristics made them appear to be invalid.
- Missile terminal conditions
  -- Each discrete parameter recorded in the SIMLAB was compared to the acceptable range of values determined from the Monte Carlo runs by the AIM-9 expert. Parameters to be used included:
    --- Miss distance
    --- Terminal range (range when SIMLAB flyout simulation stops at 0.1 sec before intercept)
    --- Final range rate (range rate when SIMLAB flyout simulation stops at 0.1 sec before intercept)
  -- Each discrete parameter was judged to be either acceptable (it was within the acceptable range) or unacceptable (it was outside the acceptable range).



(a) Compilation of SIMLAB Monte Carlo Runs

(b) Envelope of SIMLAB Monte Carlo Runs

(c) Comparison of Single Trial to Envelope with All Points Valid

(d) Comparison of Single Trial to Envelope with Interval a Data Valid and Interval b Data Invalid

Figure 4.1.2.2-1. Steps in Quantifying the Validity of Plotted Data

The qualitative evaluation of SIMLAB output was used when any SIMLAB input was unacceptable. This involved comparison of the general trends and shapes of missile trajectory plots and TM data by the AIM-9 expert. This evaluation will be based on the expert's familiarity with live fire results from many tests and the degree to which the launch conditions, target trajectory and velocity, or flare dispense time varies from the acceptable range.

Unacceptable matches were further analyzed to determine the cause of the mismatch and the whether the entire trial was to be judged valid or invalid:

- If any SIMLAB input was unacceptable, the values at the SIMLAB high-fidelity simulator input and at the originating high-fidelity simulation computer output were compared.
  - -- If the originating value agreed with the SIMLAB input (i.e., both were unacceptable), the cause of the mismatch was judged to be non-ADS-related.
  - -- If the originating value was acceptable, the cause of the mismatch was judged to be ADS-related and was further analyzed under Test Objective 4.
  - -- The qualitative evaluation of the SIMLAB output by the AIM-9 expert determined if the trial was valid or invalid.
- If all SIMLAB inputs were acceptable, but some of the SIMLAB outputs were unacceptable, the cause was assumed to be related to operation of the SIMLAB and was non-ADS-related. The overall performance of the missile simulation was assessed by the AIM-9 experts to determine if the trial was valid or invalid.

4.1.2.3 Validation Results

The following missile simulation parameters were checked by the AIM-9 experts before linked testing began and were determined to be acceptable (these were not varied throughout the linked testing periods):

- The apparent IR intensity of the target.
- The preset flare parameters (dispense rate, temperature, ejection angle).

The acceptability of SIMLAB results for quantitative evaluation was subsequently based on:

- All launch parameters being within the shot box.
- The target executing a flat (constant altitude), constant acceleration turn during the missile flyout.

<u>SIMLAB Standalone Runs of LPN-15, Exact Launch Conditions</u>

The SIMLAB standalone runs were performed which used the exact LPN-15 launch conditions. The results of the missile trajectories from these runs were used to determine the envelopes of bounding values (as described in Fig. 4.1.2.2-1). The envelopes were then compared to the actual LPN-15 data in Figures 4.1.2.3-1 through 4.1.2.3-3. These figures show the following:

- There were variations in the missile flyouts from run-to-run, even when identical launch conditions and target trajectories were input to the SIMLAB on each run. The AIM-9M seeker did not respond to the inputs in exactly the same way every time. However, the run-to-run variations are relatively small resulting in narrow envelopes during the midcourse phase of the flyout.
- The "God's-eye" view (Fig. 4.1.2.3-1) shows very good agreement between the SIMLAB results and the live test.
- The side views (Figs. 4.1.2.3-2 and 4.1.2.3-3) show less agreement. For a short time at the start of its flyout, the SIMLAB missile flew slightly above the live missile. However, for most of its flyout, the SIMLAB missile flew significantly below the live missile and approached the target from a smaller angle relative to the horizontal direction.
  - -- The live missile appeared to take longer for its initial guidance correction (at the start of its flyout, the AIM-9 flies without any steering in order to safely separate from the launch aircraft). This resulted in the live missile being lower than the simulated missile and having to compensate by flying a flatter trajectory to the target.
  - -- These differences apparently resulted in the simulated missile having slightly longer (~3% longer) times-of-flight (TOF) and much smaller miss distances (~20% of LPN-15 value).
- In spite of these differences, the simulated missile responded to the target and correctly guided to it. When the AIM-9 expert examined the trajectory plots, along with the seeker telemetry data, his judgment was that the performance of the simulated missile was valid for the given scenario. Note the qualitative features in both the live and simulated missile flyouts:

    -- An initial straight "safe-separation" segment.
    -- A distinct guidance correction at the end of the "safe-separation" segment.
    -- Continual and smooth closing on the target with no gain in missile altitude.
- Note that the simulated target was modeled to execute a perfectly flat right turn, whereas the live target's altitude varied slightly. The differences in the target trajectory were minor and did not significantly affect the missile flyout.

CONCLUSIONS

- The SIMLAB standalone simulation of the missile flyout for the LPN-15 conditions was valid. (Note that the AIM-9 Program Office has accredited the SIMLAB as a valid simulation in support of AIM-9 testing.)
- There were some minor differences in the simulated missile flyout compared to LPN-15 which reflect simulation fidelity and/or validity of the LPN-15 data.
- The LPN-15 data do not necessarily give a more accurate representation of the missile in this scenario.
    -- The LPN-15 data were derived from range measurements and are subject to inaccuracies and uncertainties.
    -- The LPN-15 data represent only a single realization of the missile behavior for this scenario. As the SIMLAB results show, there were run-to-run variations in the performance of the missile seeker and guidance for the exact same scenario.
- For the above reasons, the envelope of SIMLAB standalone results were judged to give a better standard for comparison with the linked results than did the LPN-15 data. This comparison was used to determine if linking the simulators resulted in any degradation in the SIMLAB simulation performance (the SIMLAB in the linked configuration cannot represent the missile behavior any better than in the standalone configuration).
- The features noted in both the live and the standalone simulated missile flyouts can be used for qualitative validation of the linked missile flyouts.
- The missile TOF gave a better metric for quantifying overall missile behavior than did the miss distance.
    -- The SIMLAB was not designed to accurately model the terminal engagement. The missile flyout simulation stops at 0.1 sec from intercept, and the miss distance is estimated by dead reckoning the target and missile velocity vectors to the point of closest approach (the last missile entity state PDU is generated when the missile flyout simulation stops).
    -- The distribution of miss distances from the SIMLAB results did not give additional insight into the validity of the overall missile performance.
    -- Consequently, the miss distance was not used in subsequent validity analyses.

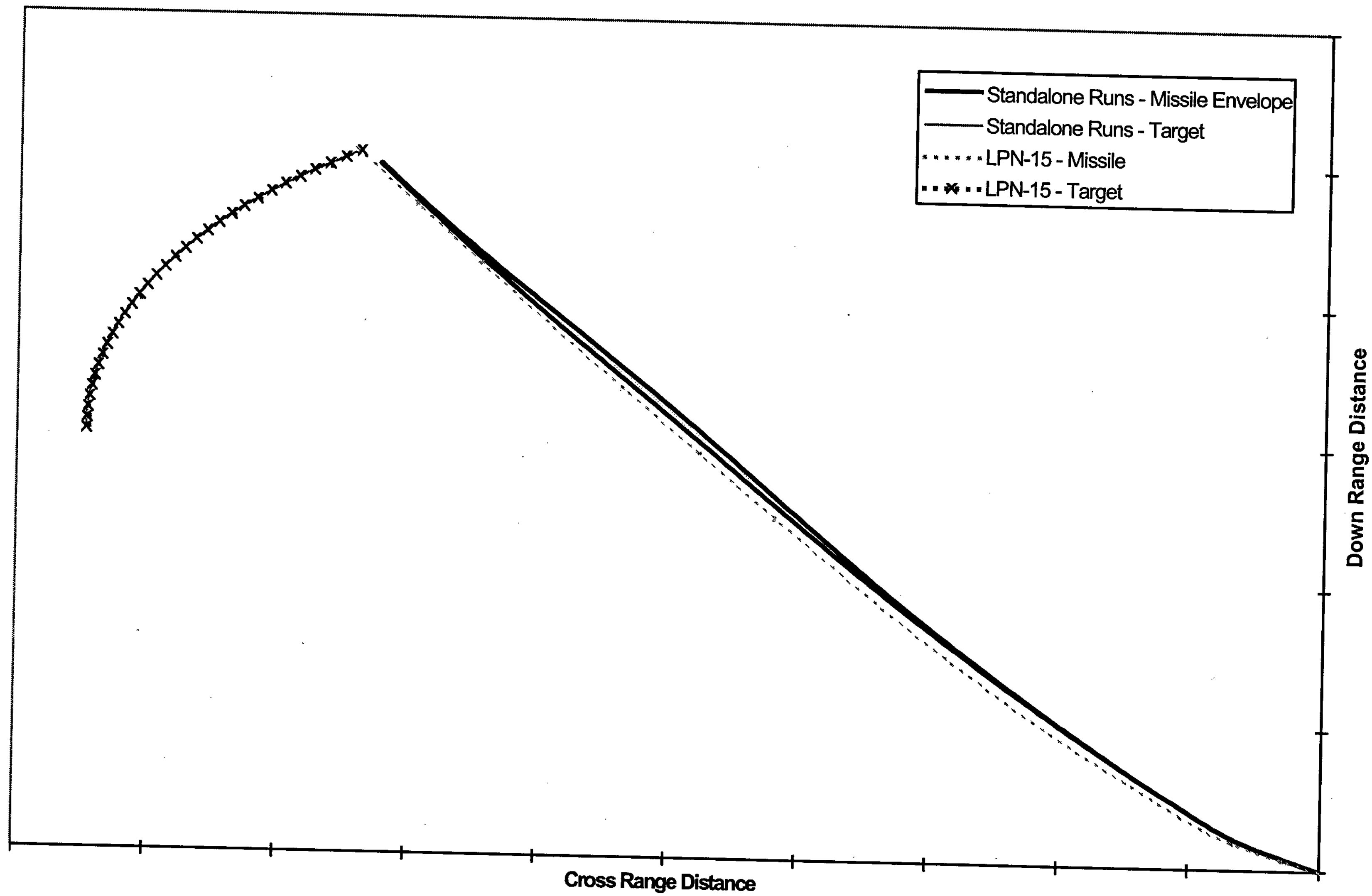


Figure 4.1.2.3-1. Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) Compared to LPN-15 Data - "God's-Eye" View

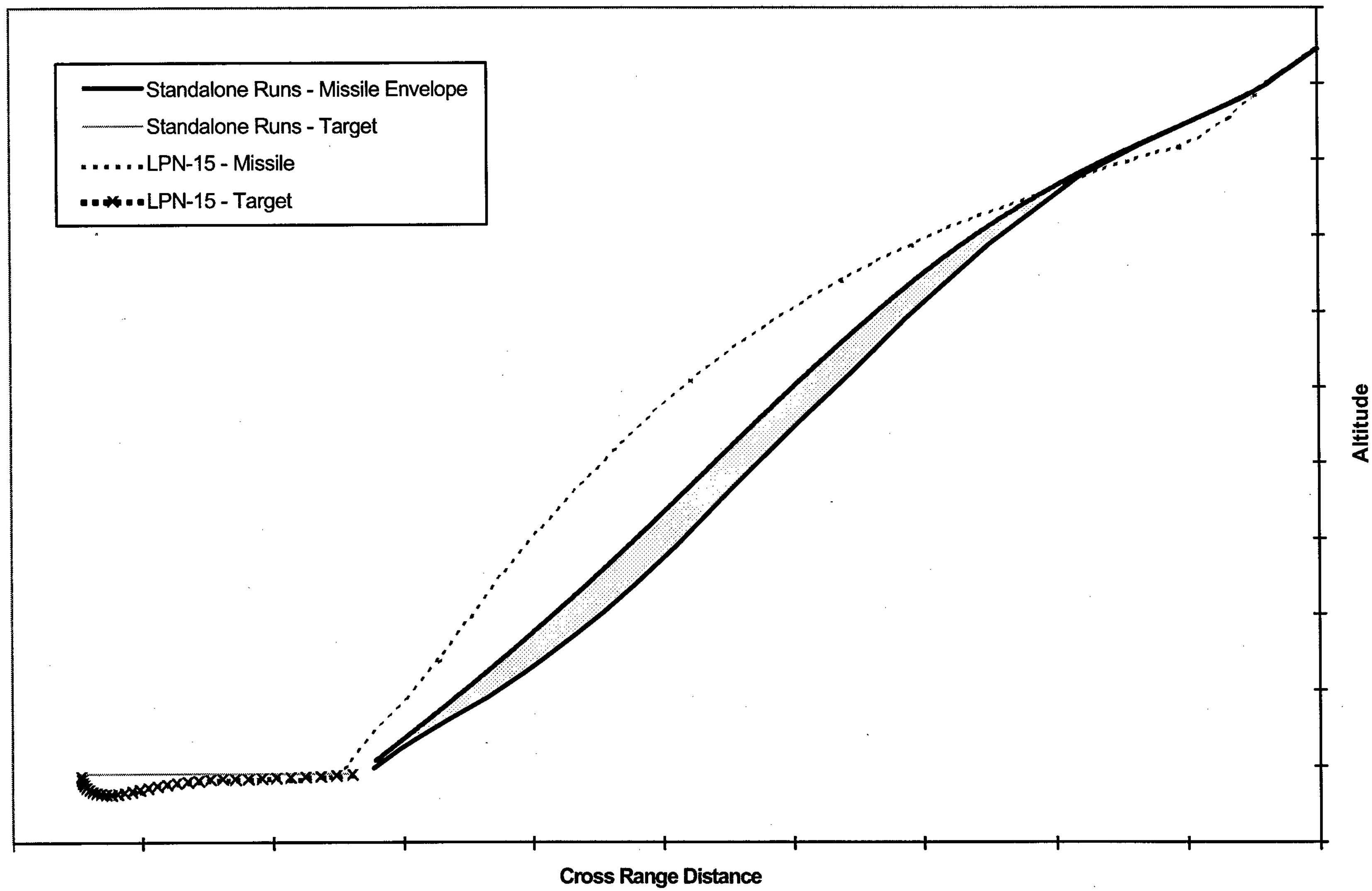


Figure 4.1.2.3-2. Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) Compared to LPN-15 Data - Side View #1

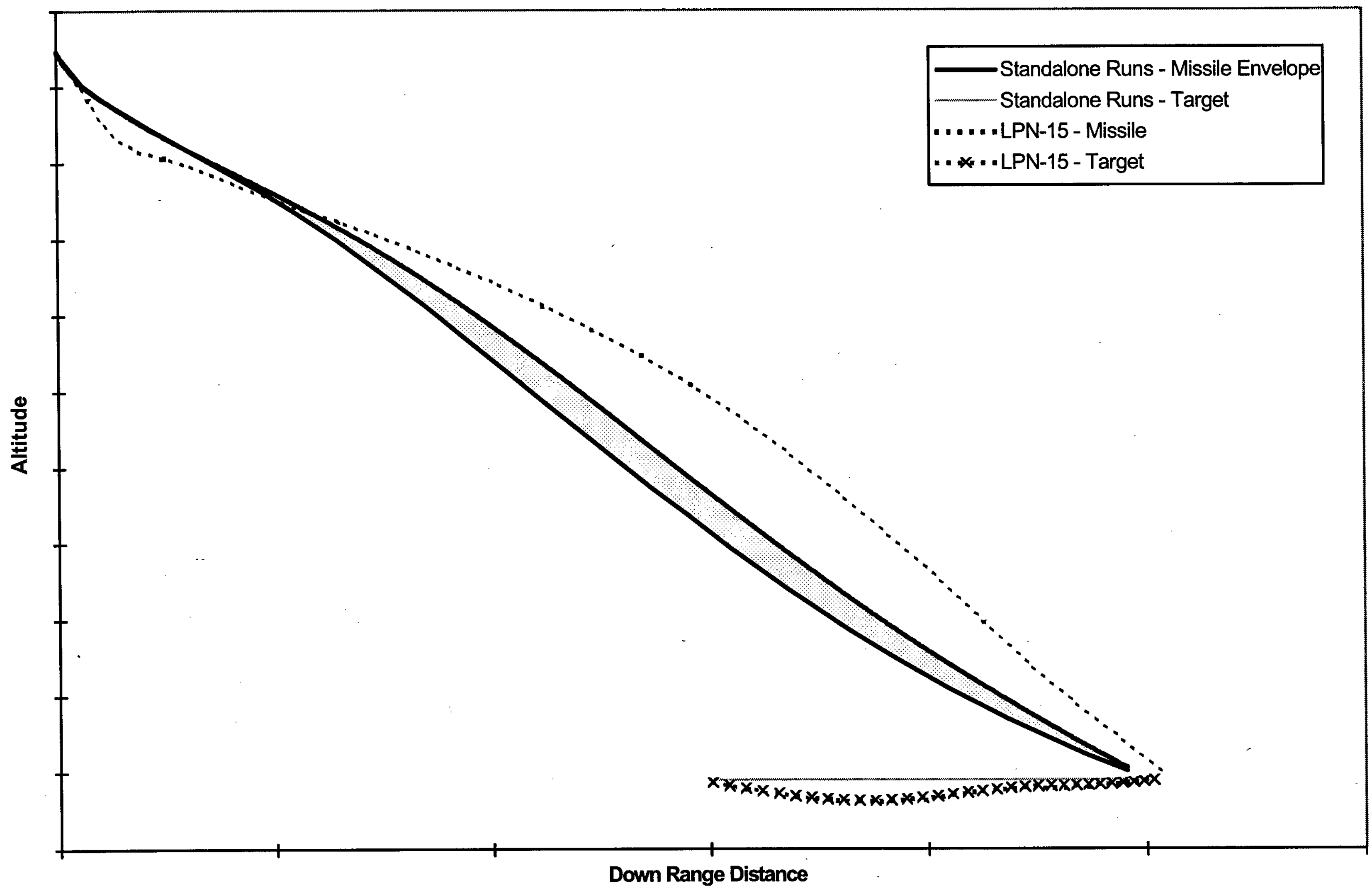


Figure 4.1.2.3-3. Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) Compared to LPN-15 Data - Side View #2

SIMLAB Standalone Runs of LPN-15, Monte Carlo Launch Conditions

The SIMLAB standalone runs were performed in which the shooter and target launch conditions were determined by Monte Carlo sampling of the shooter and target inputs about the LPN-15 profile. The launch conditions for each run were randomly selected and could have any value within the shot box with equal probability. The results of the missile trajectories from these runs were used to determine the envelopes of bounding values (as described in Fig. 4.1.2.2-1). The envelopes were then to be compared to the missile flyouts from the linked runs. The resulting envelopes are shown in Figures 4.1.2.3-4 through 4.1.2.3-6. These figures show the following:

- The envelope for the "God's-eye," or horizont al, view (Fig. 4.1.2.3-4) shows the missile flyouts all originating from a common point. This is because the SIMLAB reference frame was defined such that the missile launch point was always the origins of the down range and cross range axes. This envelope broadened as the missile flew out toward the target because of variations in the lead and target aspect angles selected for the various runs. The resulting funnel was over 5000 ft wide at the end of the missile flyouts. This funnel might be able to identify invalid flyouts in which the discrepancy occurred near the launch point (i.e., shortly after launch). However, significant deviations from a correct missile trajectory might occur later in the flyout and not fall outside this envelope.

- The envelopes for the side views (Figs. 4.1.2.3-5 and 4.1.2.3-6) neither originate nor terminate at a common point. This is because the SIMLAB reference frame used the actual missile and target altitudes in the vertical direction. The resulting envelopes were nearly constant in size in the vertical direction throughout the missile flyouts. This size was about the maximum allowable range of altitudes for either the shooter or the target at launch, 1000 ft. As with the horizontal envelope, significant deviations from a correct missile flyout could be "hidden" inside such a broad envelope.

These envelopes were too broad for distinguishing between acceptable and unacceptable missile trajectories from the linked runs. This was demonstrated to be the case from the following:

- When the missile flyouts from the Mission Rehearsal and the V&V Mission were qualitatively examined, the missile was seen to be improperly lofting to an altitude above the shooter before finally losing altitude to intercept the target. This was improper missile behavior, since the shooter was at a higher altitude than the target. The LPN-15 results (Figs. 4.1.2.3-2 and 4.1.2.3-3) show that the missile should not loft under these conditions.
- However, when the invalid lofting trajectories wer e compared to the vertical envelopes, a number of these invalid flyouts fell entirely within the envelopes and would have been judged valid according to the envelope criteria. An example from the V&V Mission (10/29/96) is shown in Figure 4.1.2.3-7.

Hence, the validation technique of comparing the missile flyouts from the linked runs to these envelopes (those resulting from the launch conditions being randomly selected from the shot box)

failed. The envelopes could be narrowed by significantly reducing the shot box, but the pilots would not have been able to consistently achieve a much narrower box.

CONCLUSIONS

- The quantitative validation technique based on comparing the missile flyouts from the linked runs to the envelopes resulting from Monte Carlo sampling of launch conditions had to be abandoned. It was incapable of identifying many of the invalid lofting missile trajectories.
- The missile trajectories from the SIMLAB standalone runs all have similar shapes and the same qualitative features:
  - -- An initial straight "safe-separation" segment.
  - -- A distinct guidance correction at the end of the "safe-separation" segment.
  - -- Continual and smooth closing on the target with no gain in missile altitude.
- The envelopes resulting from SIMLAB standalone runs which all used the same launch conditions and target trajectory were narrow enough to be useful for comparisons with linked results (see Figs. 4.1.2.3-1 through 4.1.2.3-3).
- The validation method to be used for the linked runs had to be modified to util ize both qualitative and quantitative validation.
  - The qualitative method was to compare the shape of the missile trajectory to that for LPN-15 by looking for all the qualitative features noted above.
    - -- This method identified the missile lofting as an invalid flyout.
  - The quantitative method was to involve SIMLAB standalone runs using the linked result in which the launch conditions most closely matched those of LPN-15.
    - -- On each trial, the exact launch conditions of the best linked run were to be used.
    - -- The results of 20 missile flyouts were to be used to define an envelope of valid flyouts.
    - -- The flyout of the linked run was to be validated by comparing it to the envelope.

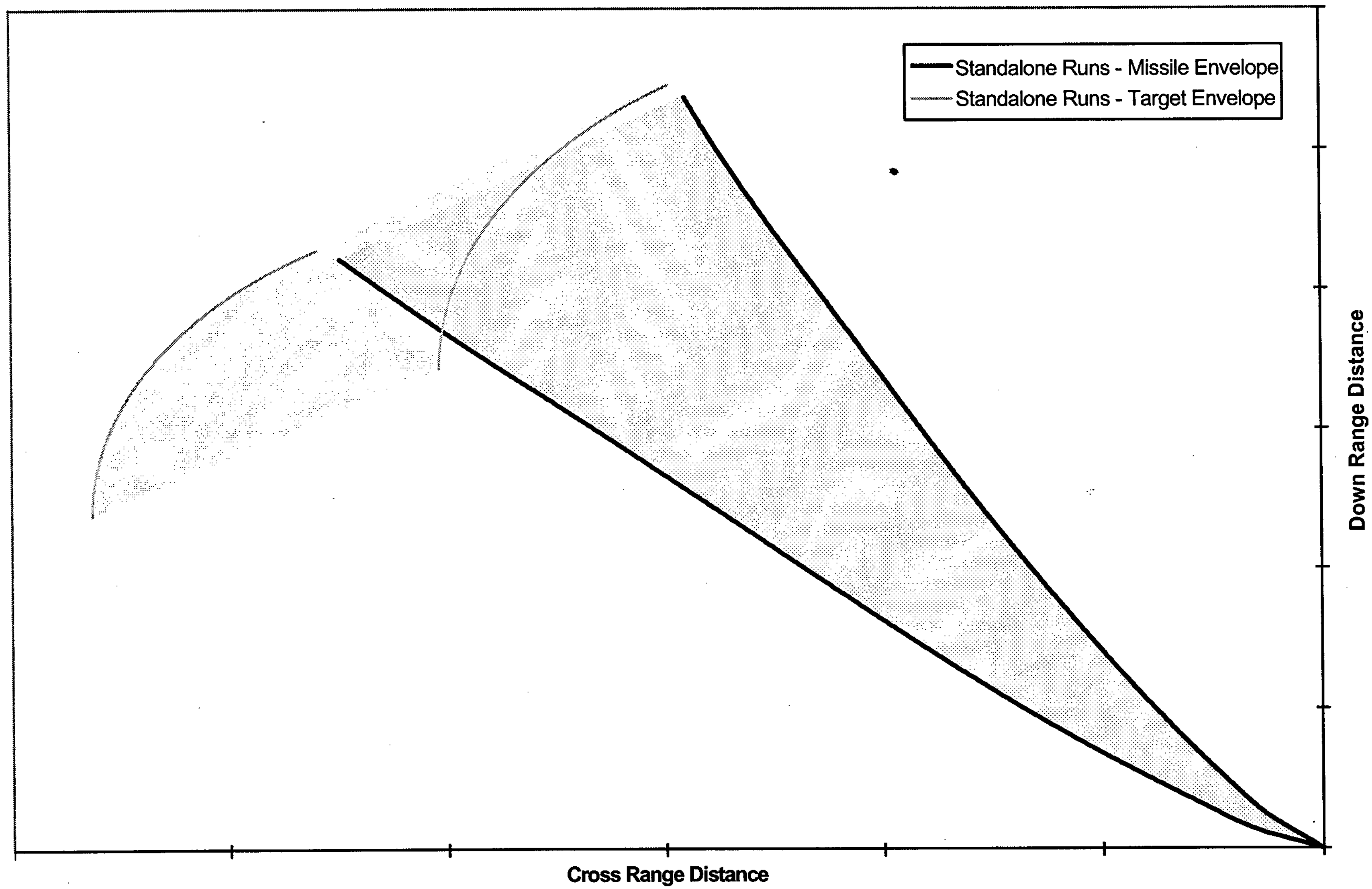


Figure 4.1.2.3-4. Envelope of SIMLAB Standalone Runs (using launch conditions randomly selected from shot box) - "God's-Eye" View

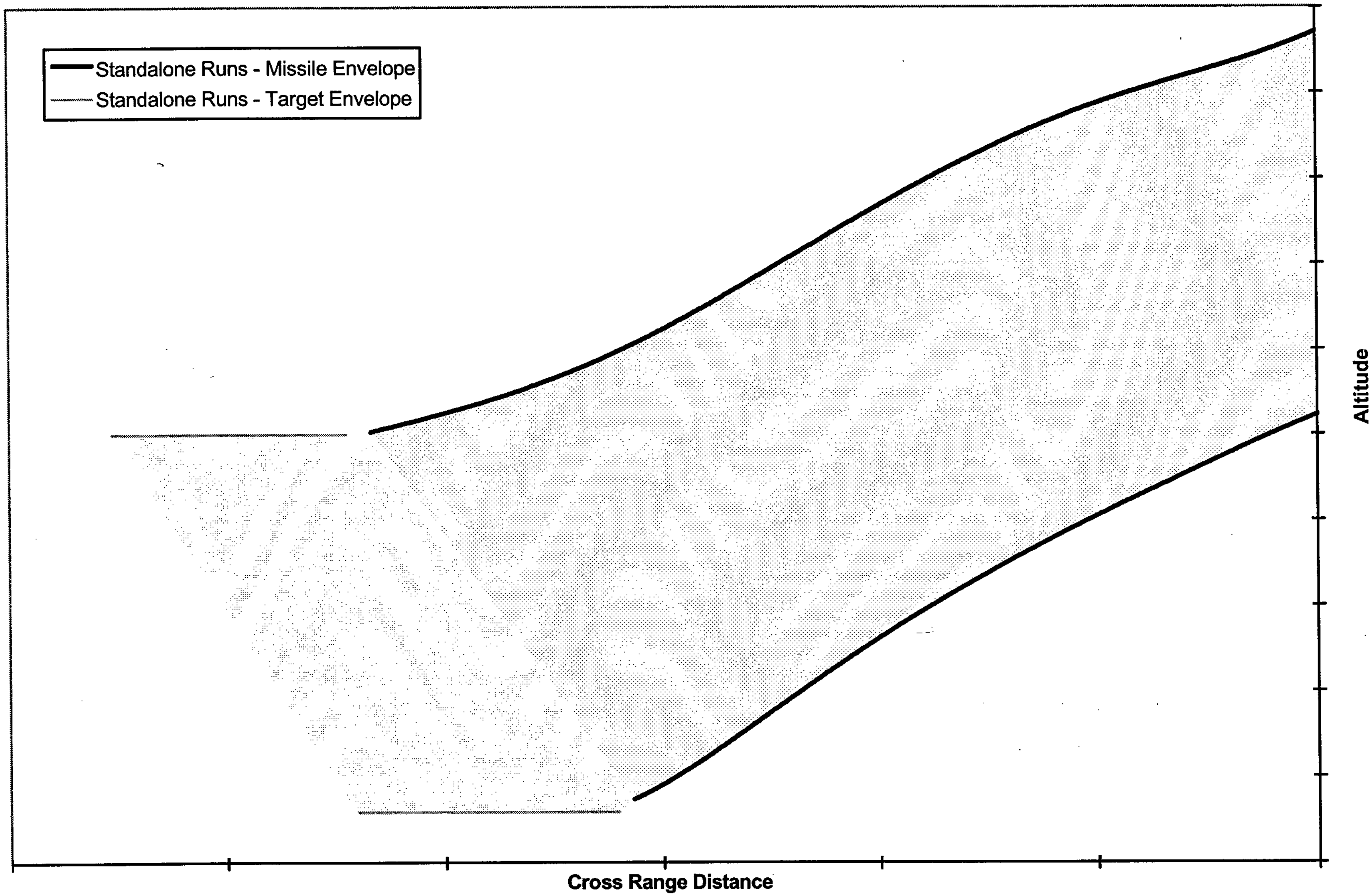


Figure 4.1.2.3-5. Envelope of SIMLAB Standalone Runs (using launch conditions randomly selected from shot box) - Side View #1

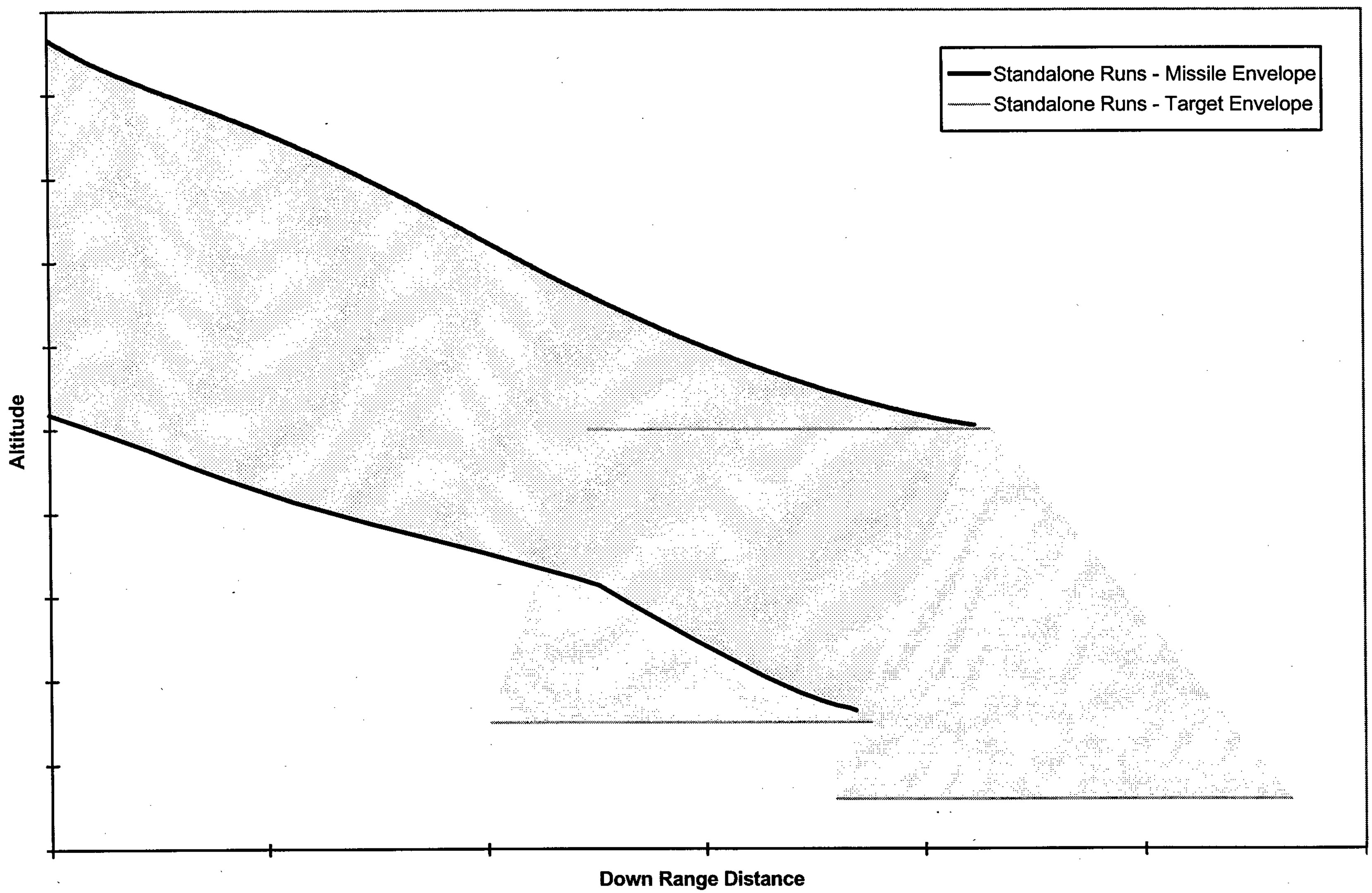


Figure 4.1.2.3-6. Envelope of SIMLAB Standalone Runs (using launch conditions randomly selected from shot box) - Side View #2

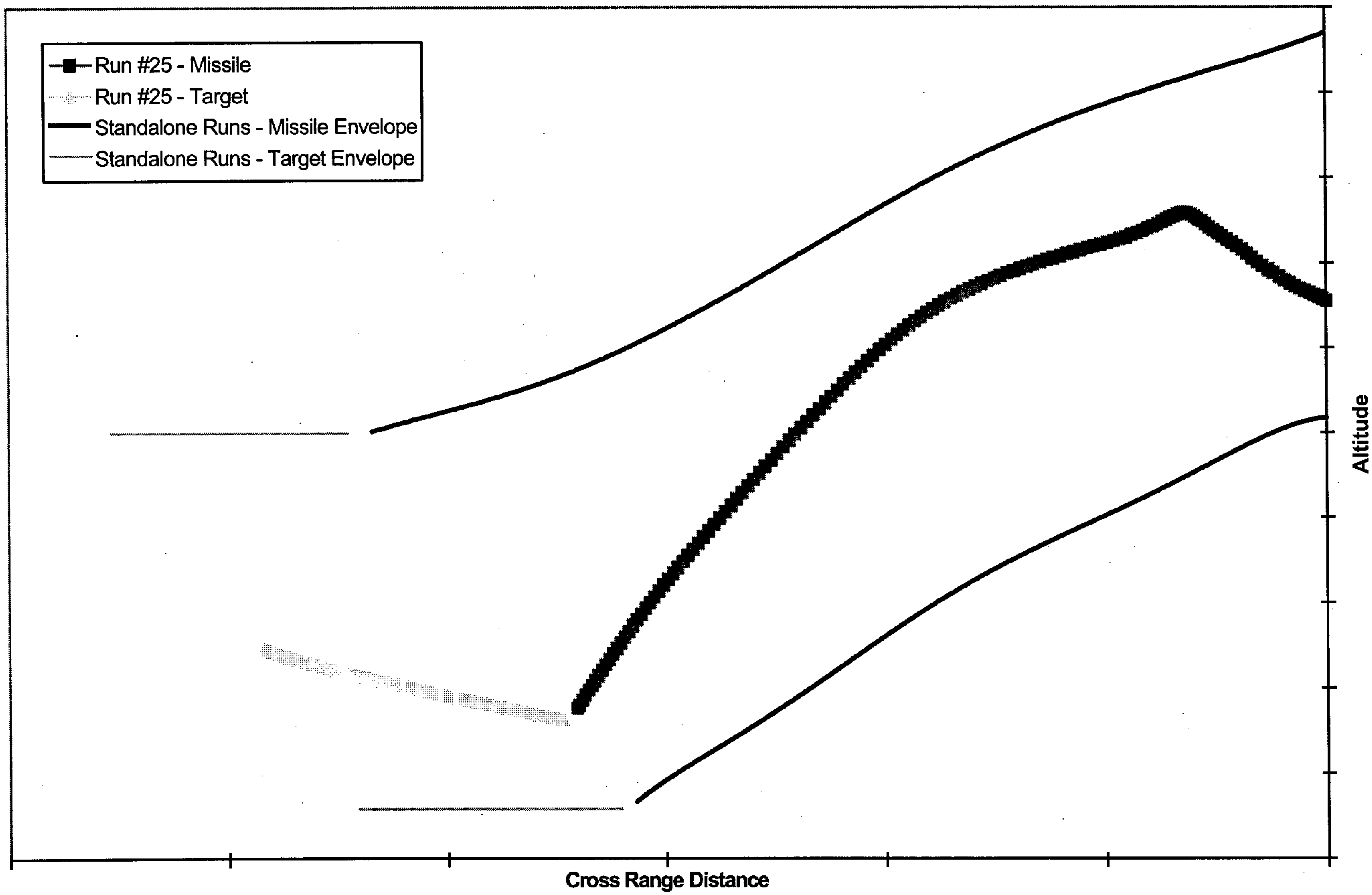


Figure 4.1.2.3-7. Missile Flyout for Run #25 (10/29/96) Compared to Envelope of SIMLAB Standalone Runs (using launch conditions randomly selected from shot box) - Side View #1

Validation of Linked Results

Qualitative verification of the Mission Rehearsal and V&V Mission results revealed that the missile was improperly lofting to an altitude above the shooter before finally losing altitude to intercept the target. The lofting was subsequently determined to be due to incorrectly inputting the down component of shooter velocity into the SIMLAB simulation, as follows:

- The shooter was at a higher altitude than the target. The shooter boresighted on the target prior to launch by dropping its nose. This caused the shooter to always be losing altitude at launch.
- Since the shooter was losing altitude, it had a positive component of down velocity (the vertical velocity component used by the NAWCWPNS simulations).
- Positive down velocities were incorrectly interpreted by the simulation as the shooter (and missile) gaining altitude at launch. (The down velocities "signs" were reversed in the SSC code in the SIMLAB and the WSSF HP/NIU computer code.)
- As a result, the missile thought it was initially going up at launch when it really should have been going down.

The lofting problem was fixed for the Parametric Study Mission (11/19/96), as was verified using the qualitative verification method. Figures 4.1.2.3-8 through 4.1.2.3-13 compare the results of the Parametric Study Mission V2 runs with the envelopes of SIMLAB standalone runs which used the exact LPN-15 launch conditions. These figures show the following correct qualitative features:

- The missile lofting problem had been solved.
- An initial straight "safe-separation" segment.
- A distinct guidance correction at the end of the "safe-separation" segment.
- The missile smoothly guided on the target representation it was given.

The six Parametric Study Mission V2 runs were examined to determine which run best matched LPN-15 for the quantitative validation. The following factors were considered:

- The smallest absolute differences between LPN-15 and the linked run for values of target aspect angle, lead angle, flare deployment time, and missile TOF.
- The smallest altitude variation of the target during the missile flyout.

These factors are compared in Table 4.1.2.3-1. This table shows that the Parametric Study Mission run which best satisfied all of the above criteria was Run #12. Thus, Run #12 was used for the quantitative verification.

Table 4.1.2.3-1. Comparison of Parametric Study Mission V2 Runs to LPN-15

Run	Delta Aspect (°)	Delta Lead (°)	Delta Flare Time (sec)	Delta TOF (sec)	Total Deltas	Target Alt. Variation (ft)
9	4.45	1.26	0.60	0.30	6.61	61.6
10	1.52	2.78	1.48	0.21	5.99	101.8
12	3.44	0.09	0.38	0.08	3.99	40.7
18	5.10	1.22	1.92	0.54	8.78	301.6
19	4.87	2.39	1.66	0.40	9.32	241.4
22	5.72	3.72	0.27	0.15	9.86	81.1

The launch conditions and target trajectory from Run #12 were used as inputs to SIMLAB standalone runs for the quantitative validation method. The SIMLAB standalone runs were performed after correcting the target initialization error in the SIMLAB reference frame (see Section 4.1.1.3). The missile flyouts for 20 SIMLAB standalone runs were used to determine the envelope of bounding values (as described in Fig. 4.1.2.2-1). The envelopes were then compared to the missile flyout from Run #12, as shown in Figures 4.1.2.3-14 through 4.1.2.3-16. These figures show the following:

- The missile flyouts during the Parametric Study Mission were in error because of the target initialization error in the SIMLAB reference frame. This is shown most clearly in the "God's-eye" view (Fig. 4.1.2.3-14).
- The first side view (Fig. 4.1.2.3-15) shows a "dip" and recovery in the missile trajectory for Run #12 compared to the SIMLAB standalone envelope. This apparently was due to errors in initializing the missile yaw and pitch for the linked runs, which were not discovered until after the linked runs, but before the SIMLAB standalone runs.

There was good agreement between the TOFs for Run #12 and those for the SIMLAB standalone runs. The TOF for Run #12 was within about 1% of the mean TOF for the 20 SIMLAB standalone runs. This, along with the qualitative comparison to LPN-15, indicates that the missile flyout for Run #12 was valid for the target representation in the SIMLAB reference frame.

CONCLUSION. The LSP results for missile flyout were invalid because of incorrect representation of the target to the missile simulation and errors in initializing the missile orientation. However, the initialization errors have since been fixed.

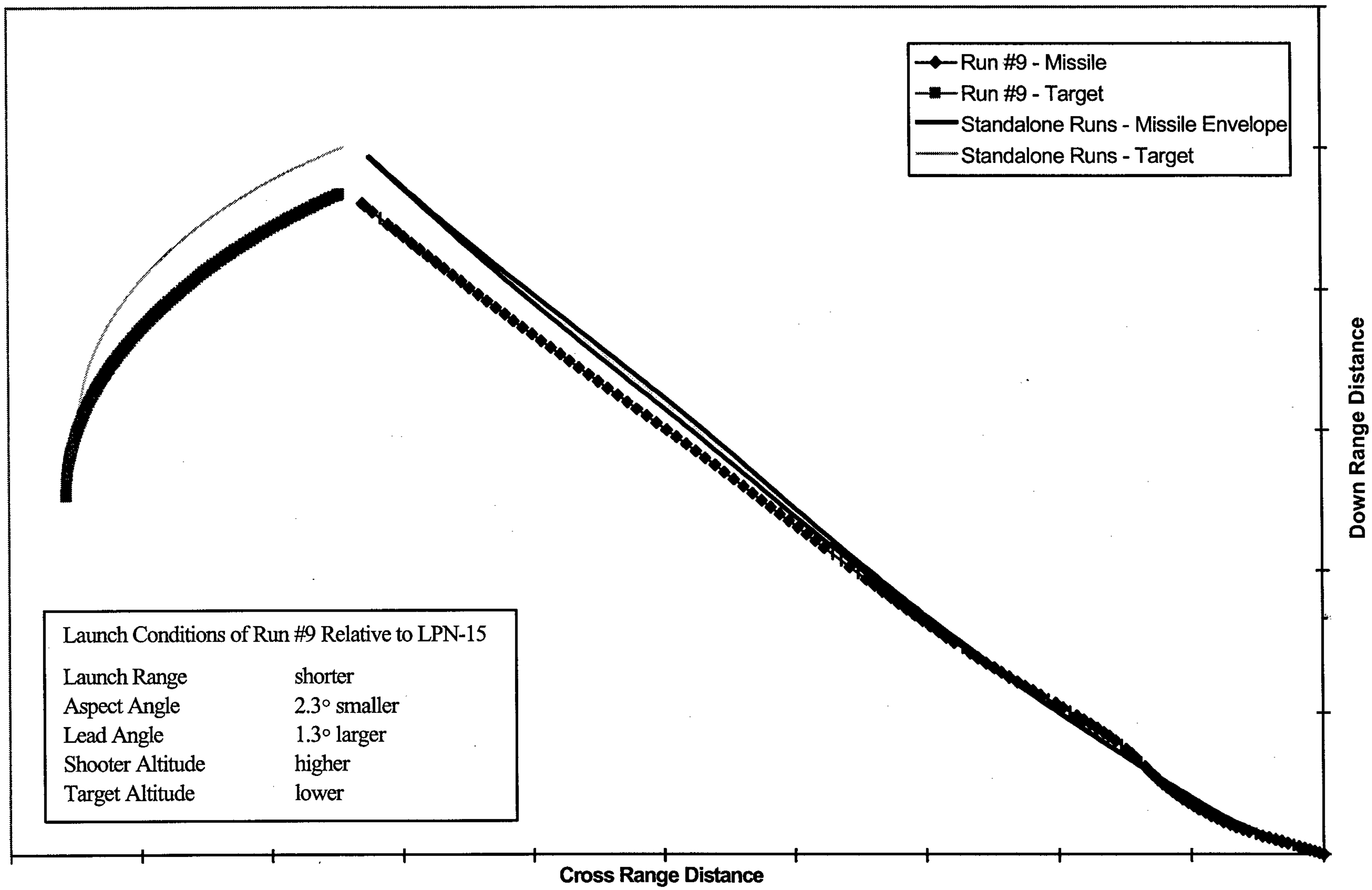


Figure 4.1.2.3-8a. Missile Flyout for Run #9 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - "God's-Eye" View

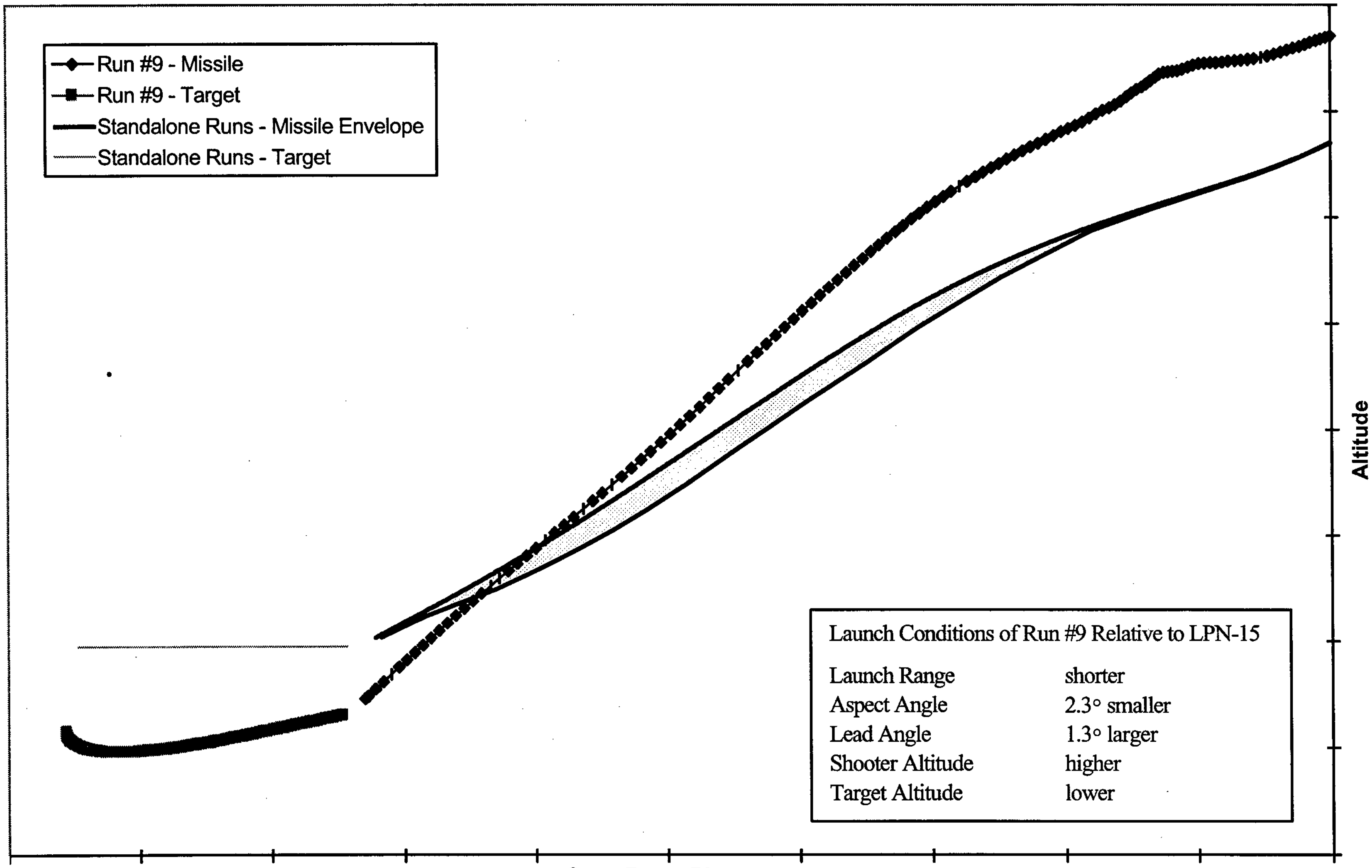


Figure 4.1.2.3-8b. Missile Flyout for Run #9 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #1

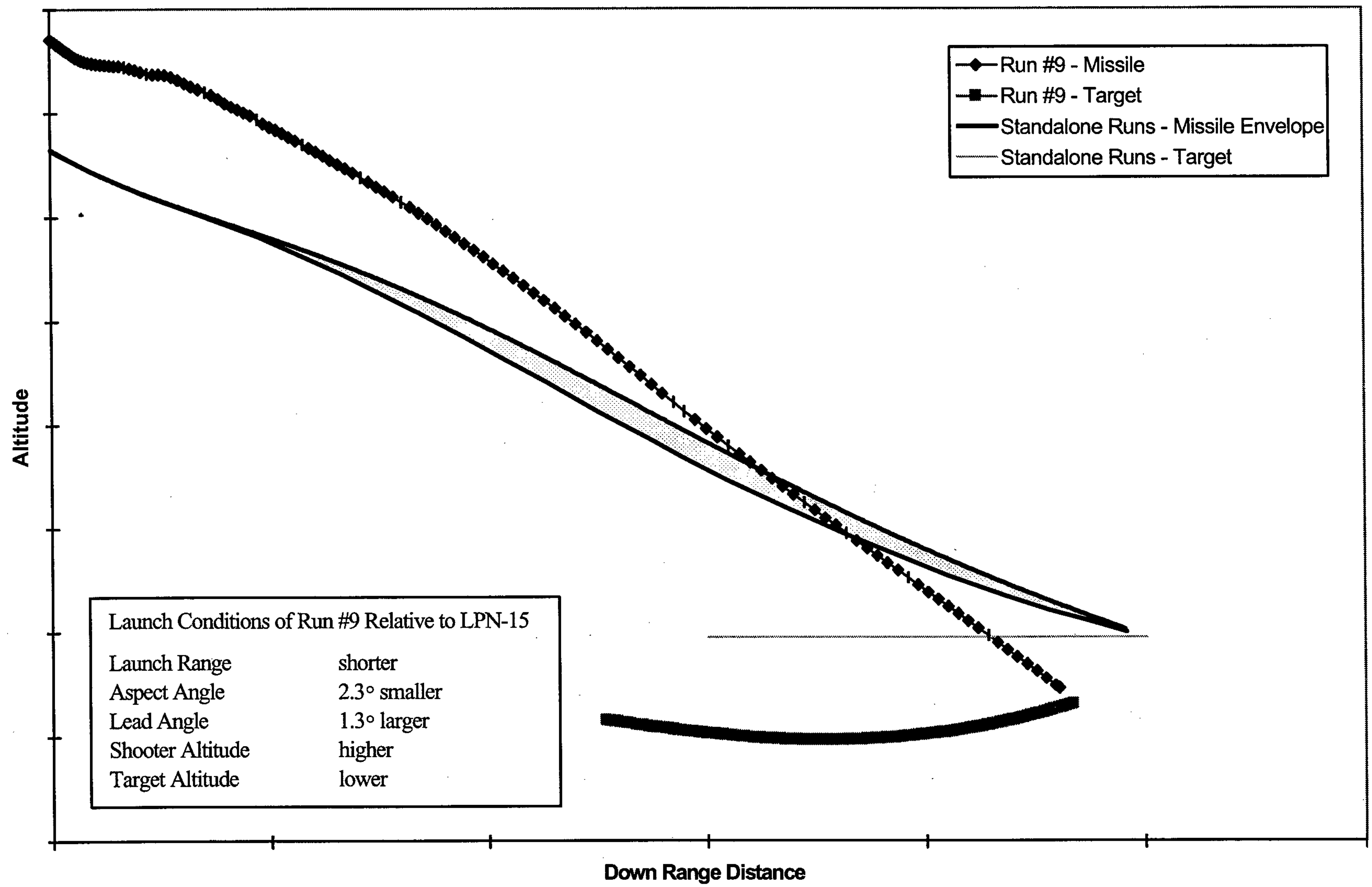


Figure 4.1.2.3-8c. Missile Flyout for Run #9 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #2

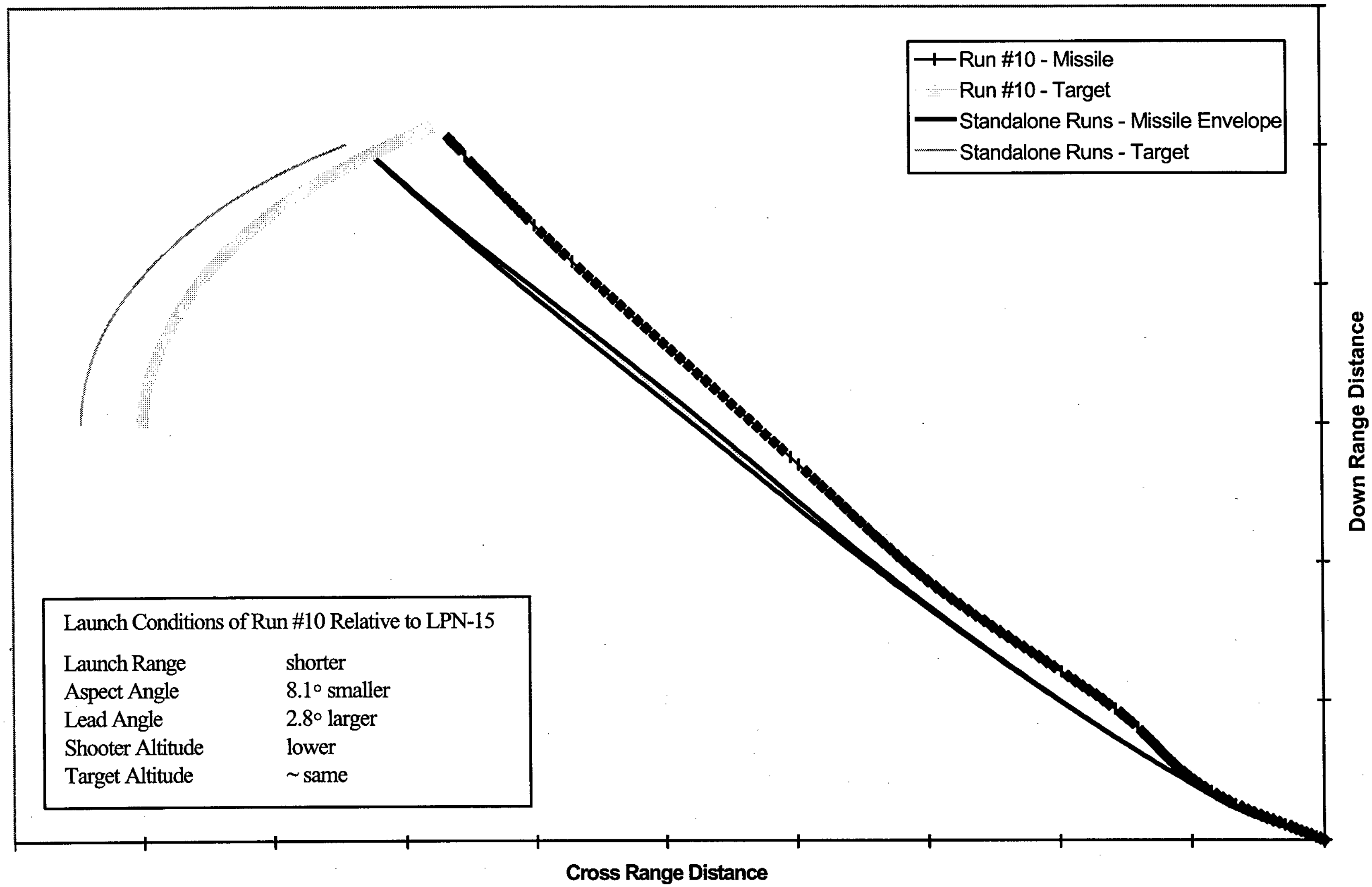


Figure 4.1.2.3-9a. Missile Flyout for Run #10 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - "God's-Eye" View

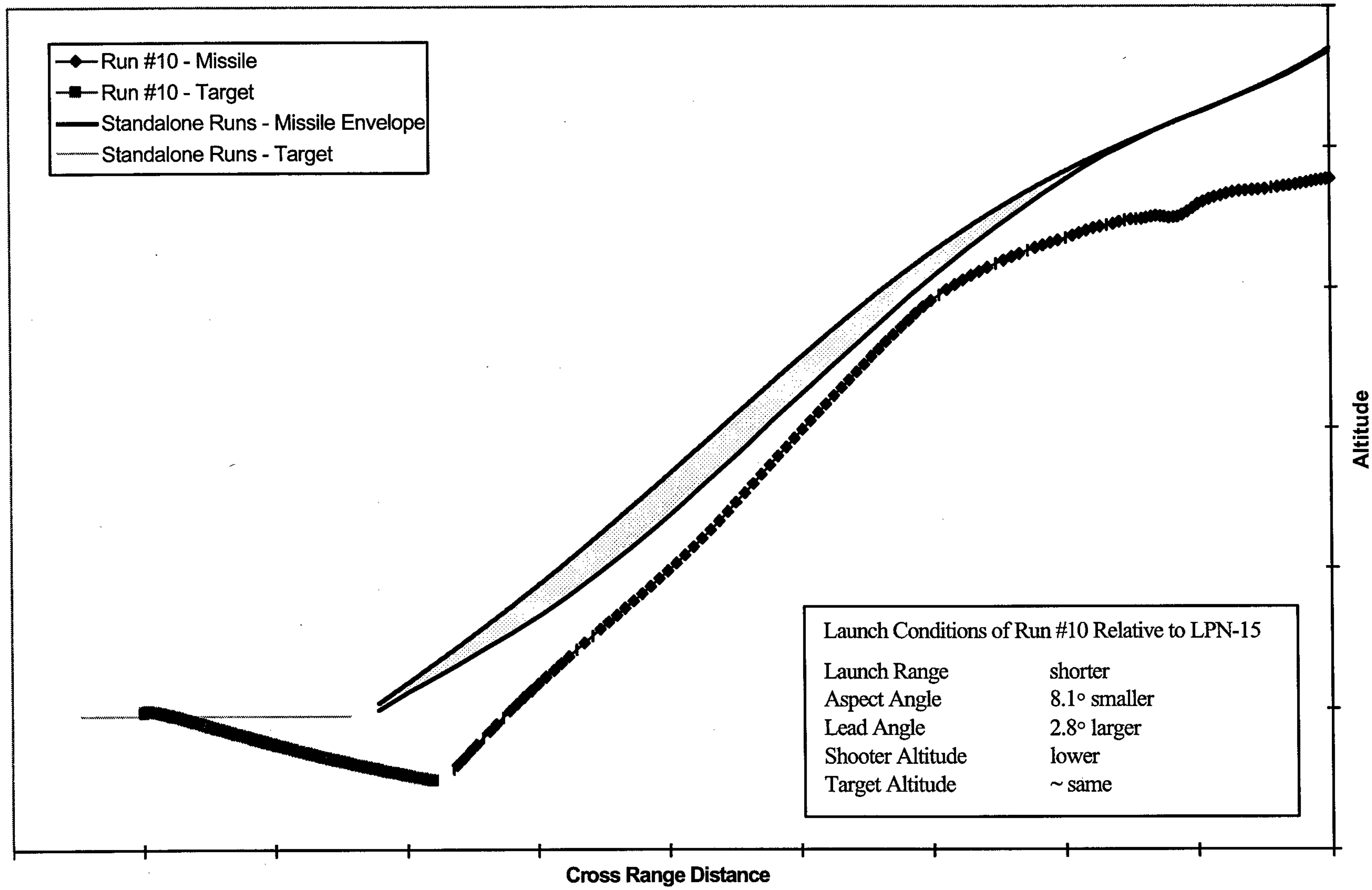


Figure 4.1.2.3-9b. Missile Flyout for Run #10 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #1

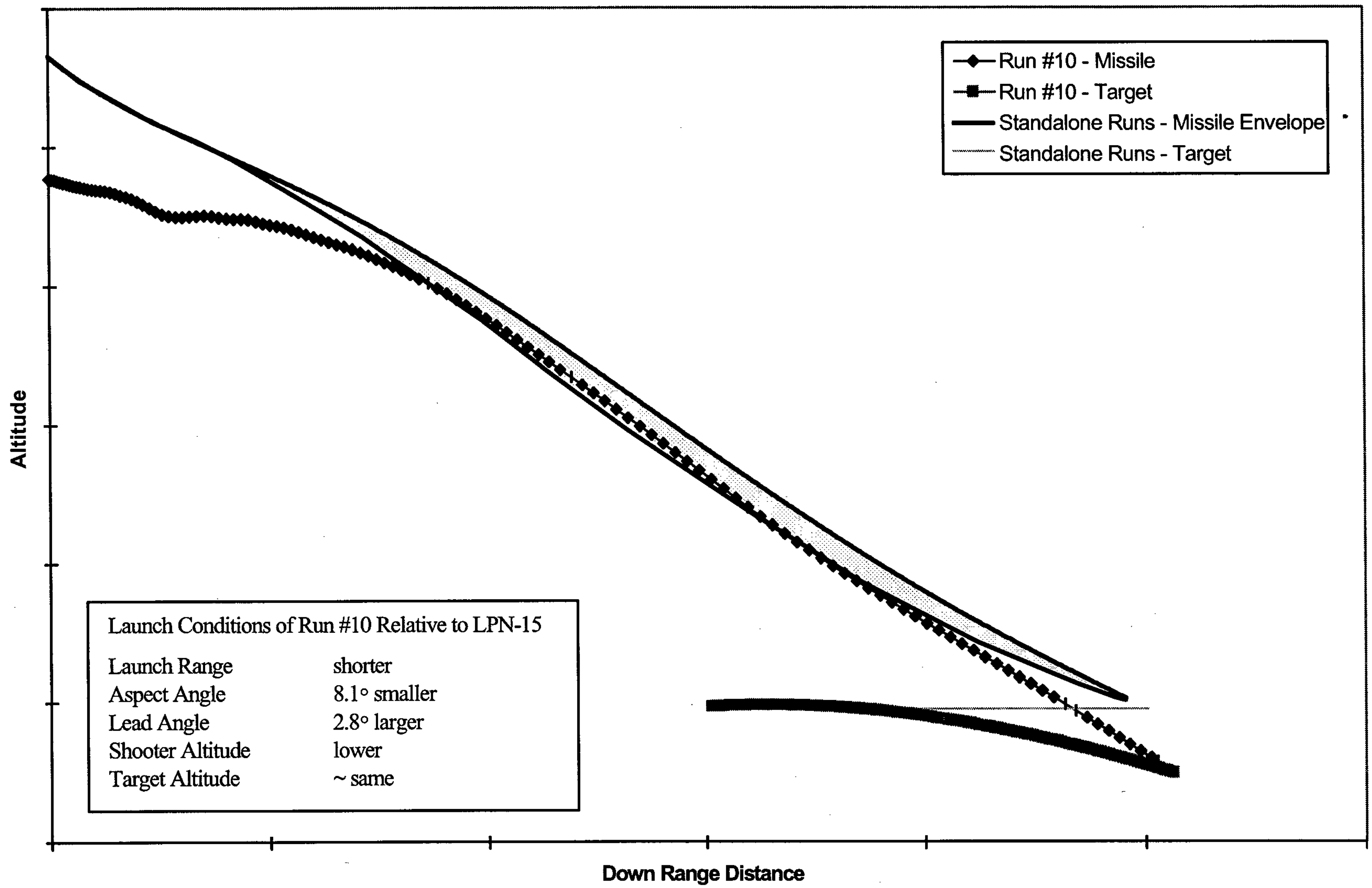


Figure 4.1.2.3-9c. Missile Flyout for Run #10 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #2

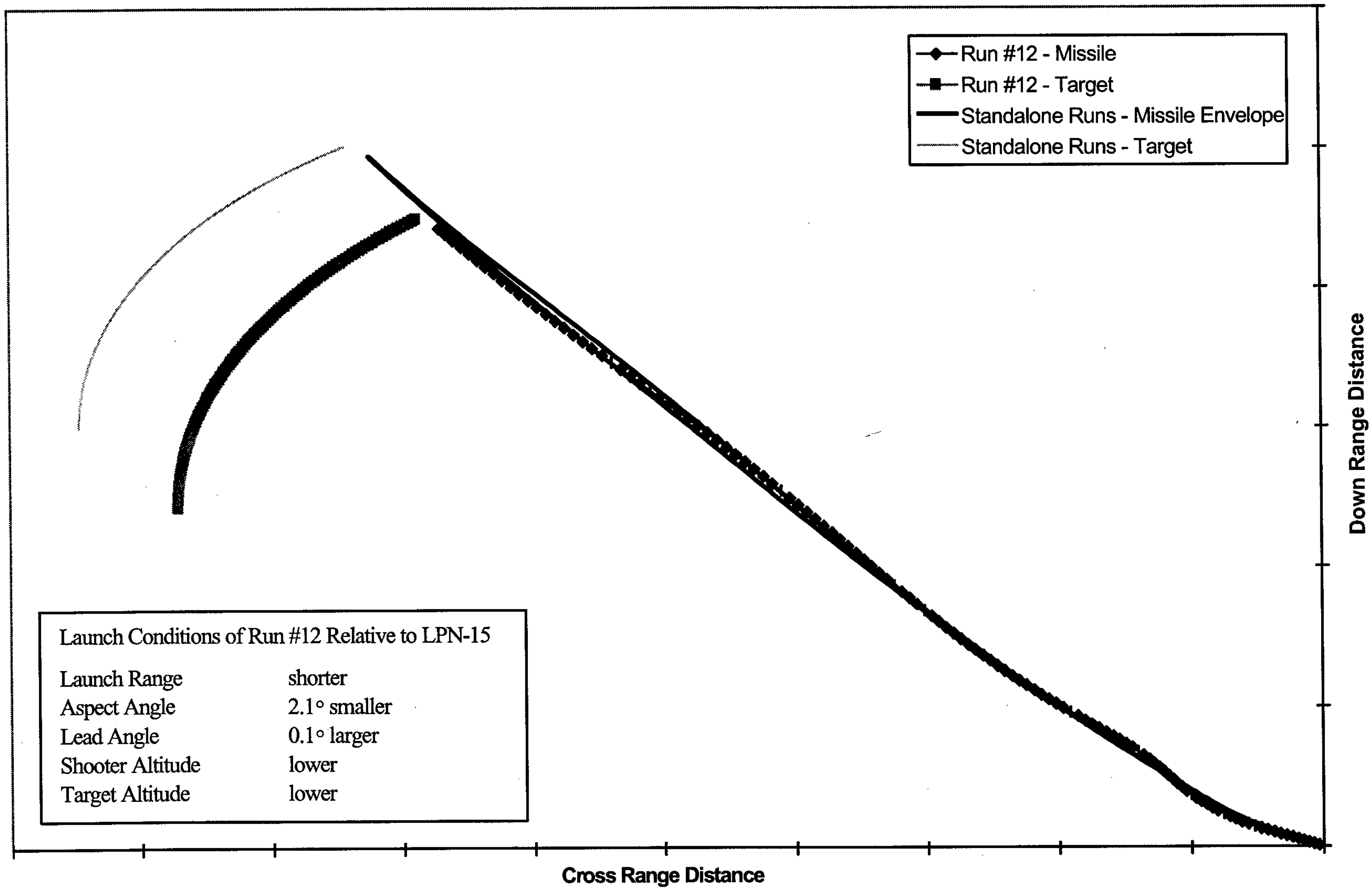


Figure 4.1.2.3-10a. Missile Flyout for Run #12 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - "God's-Eye" View

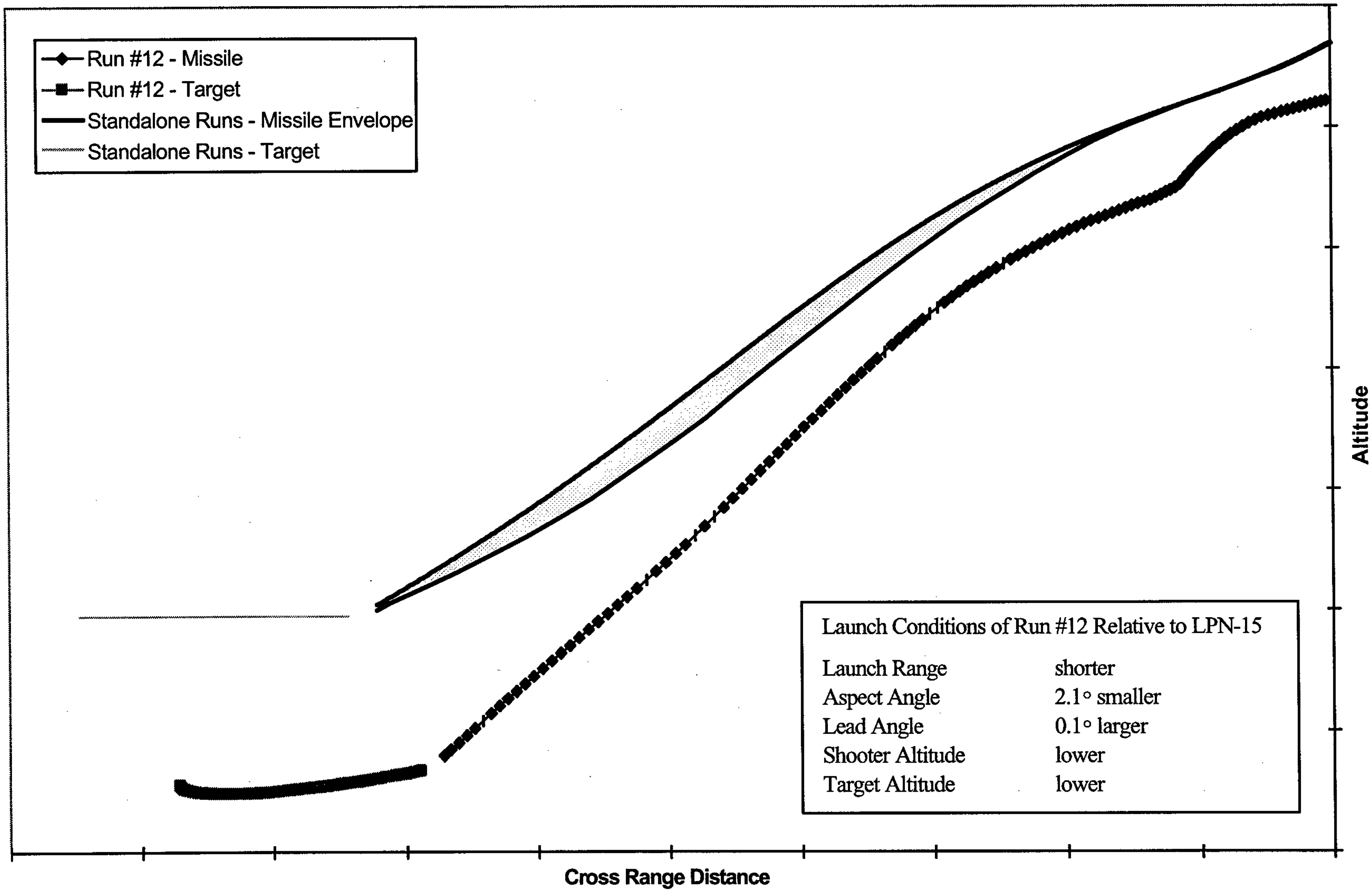


Figure 4.1.2.3-10b. Missile Flyout for Run #12 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #1

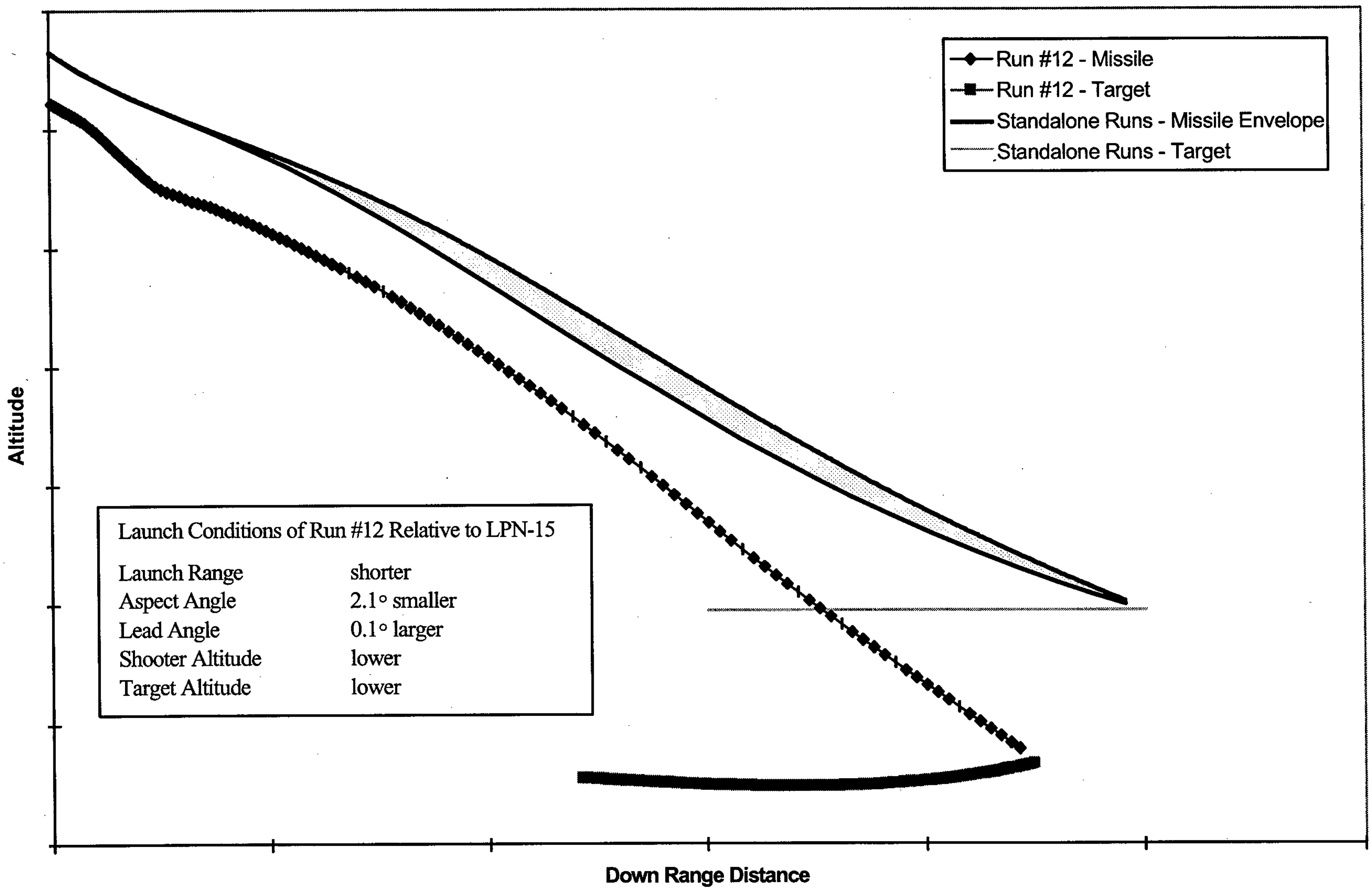


Figure 4.1.2.3-10c. Missile Flyout for Run #12 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #2

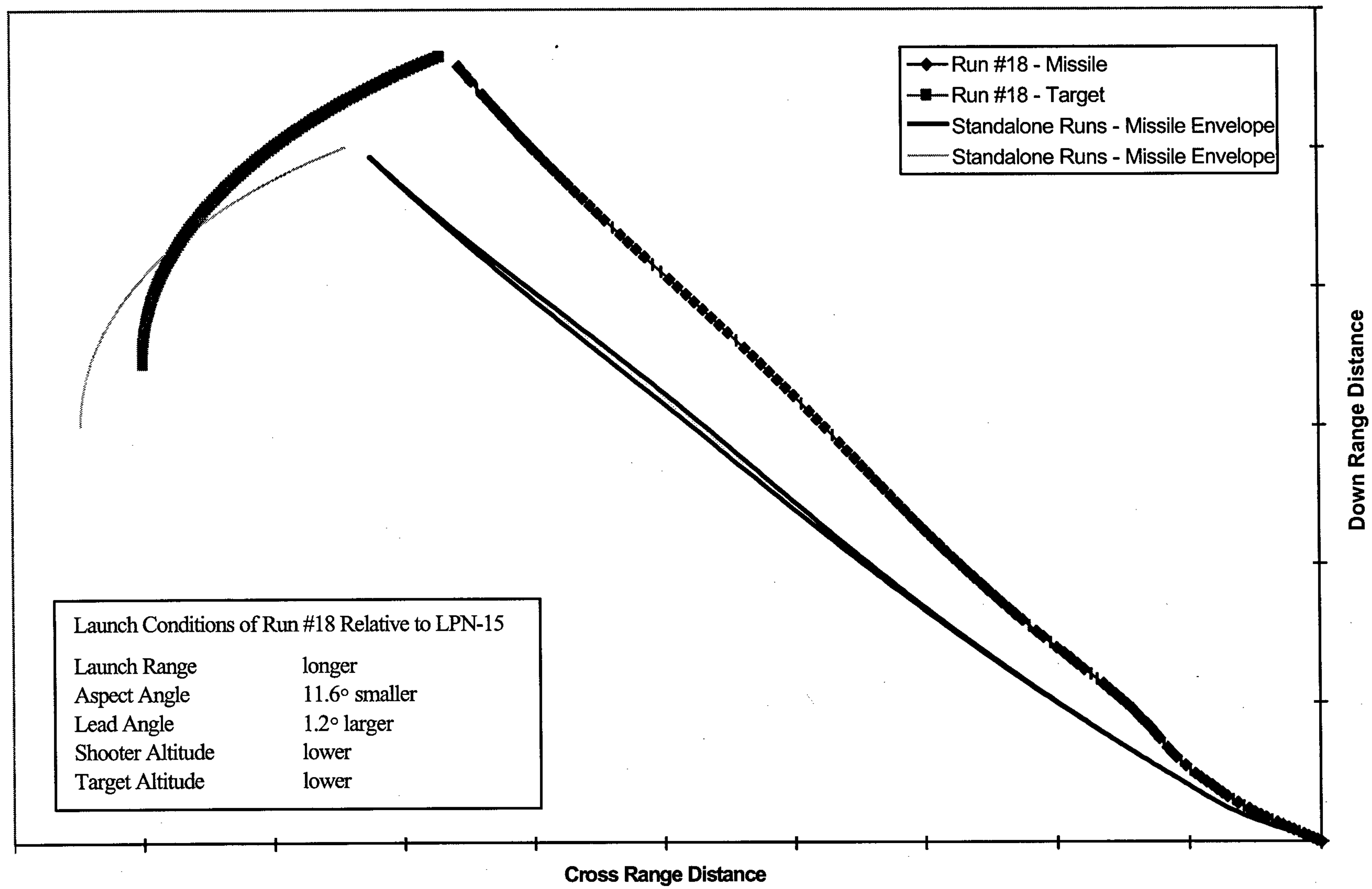


Figure 4.1.2.3-11a. Missile Flyout for Run #18 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - "God's-Eye" View

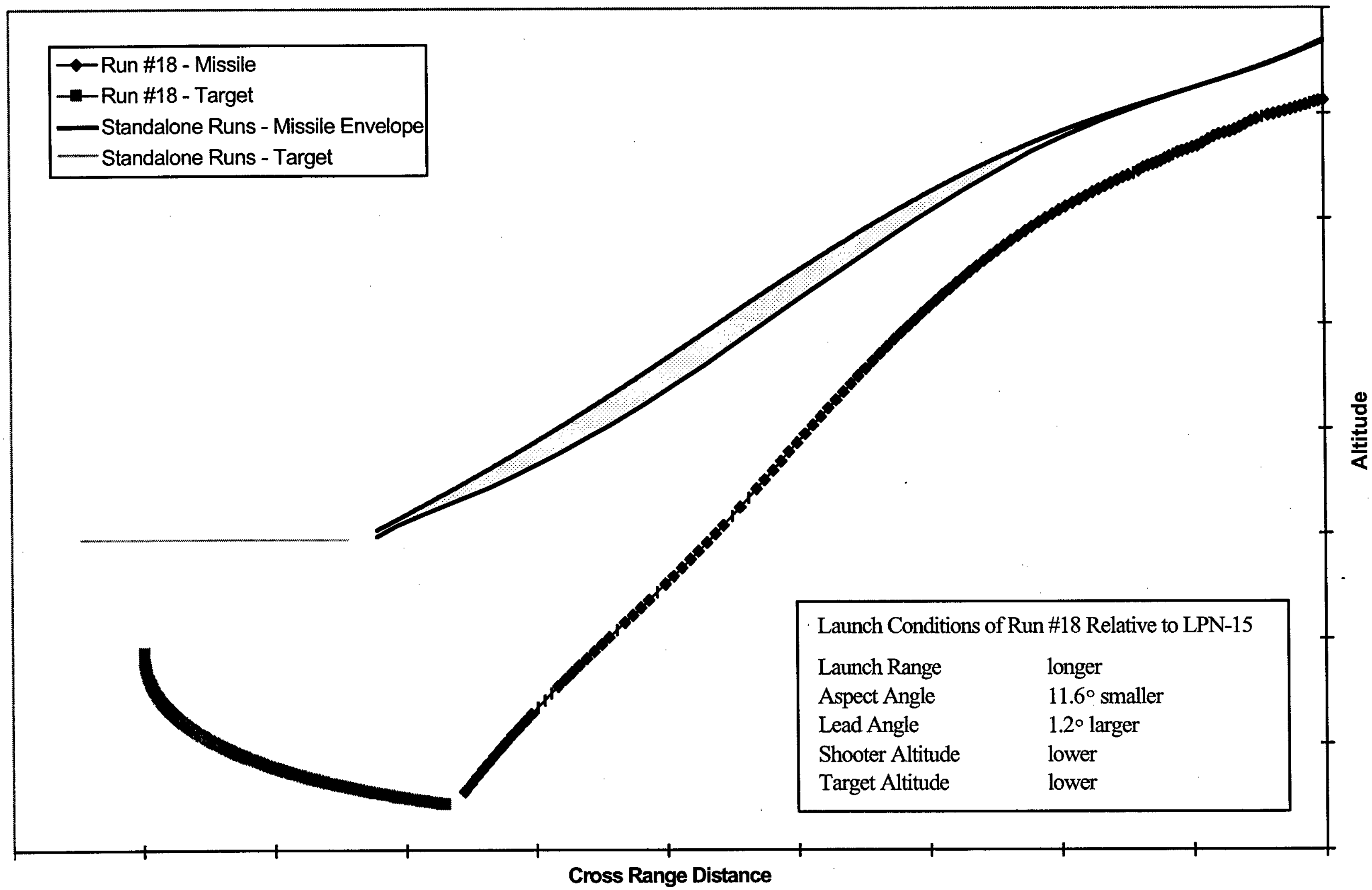


Figure 4.1.2.3-11b. Missile Flyout for Run #18 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #1

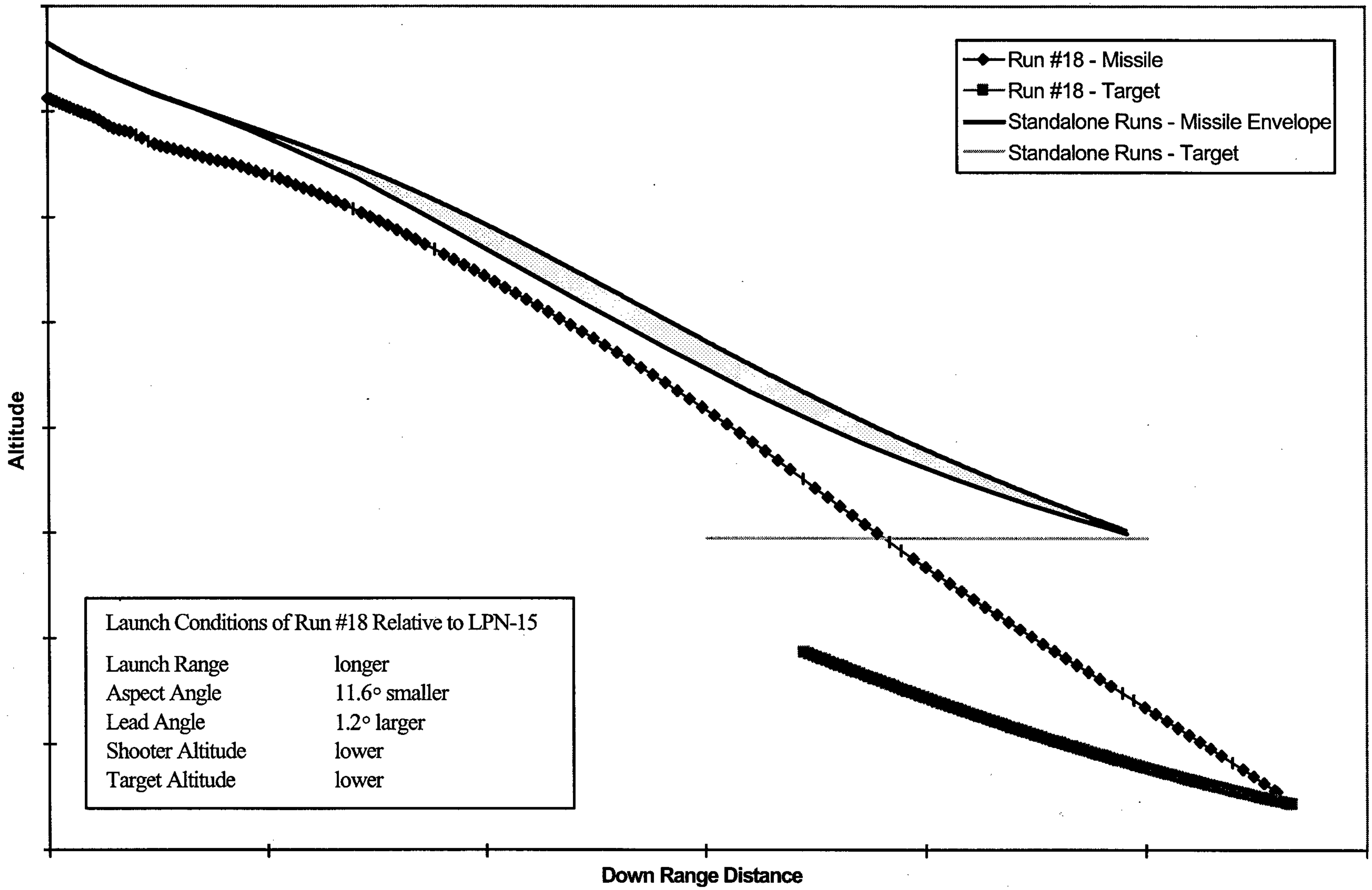


Figure 4.1.2.3-11c. Missile Flyout for Run #18 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #2

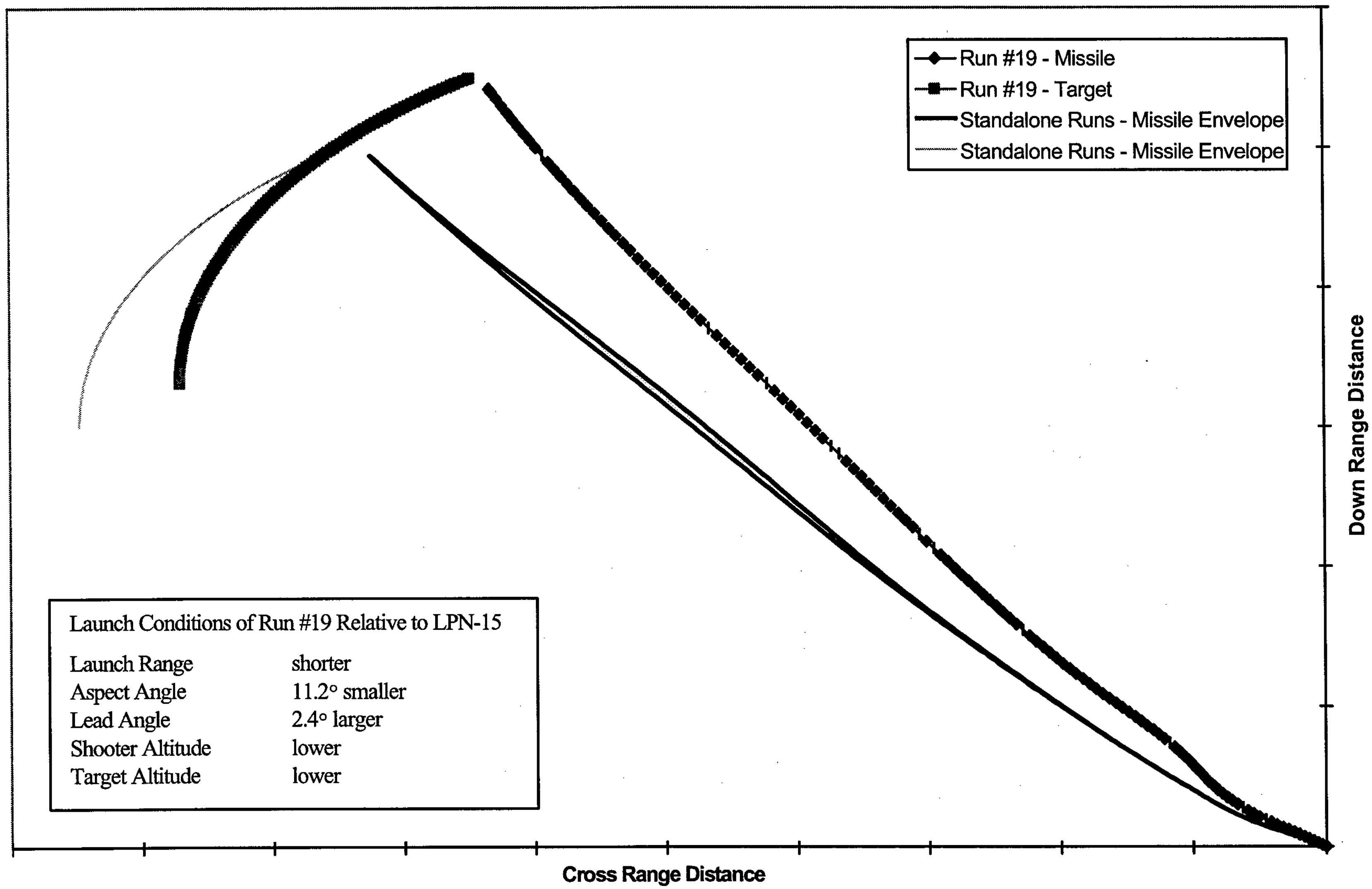


Figure 4.1.2.3-12a. Missile Flyout for Run #19 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - "God's-Eye" View

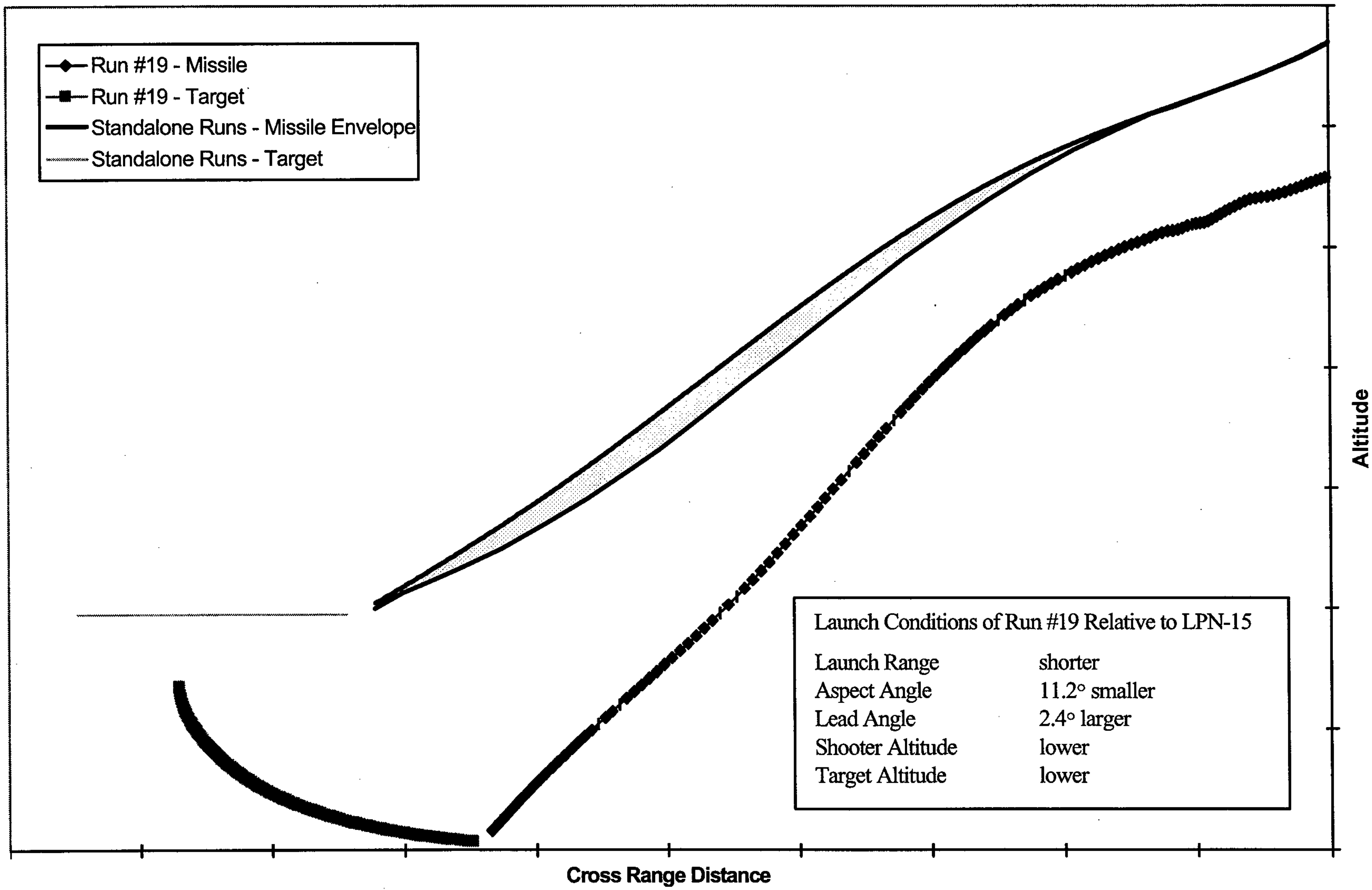


Figure 4.1.2.3-12b. Missile Flyout for Run #19 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #1

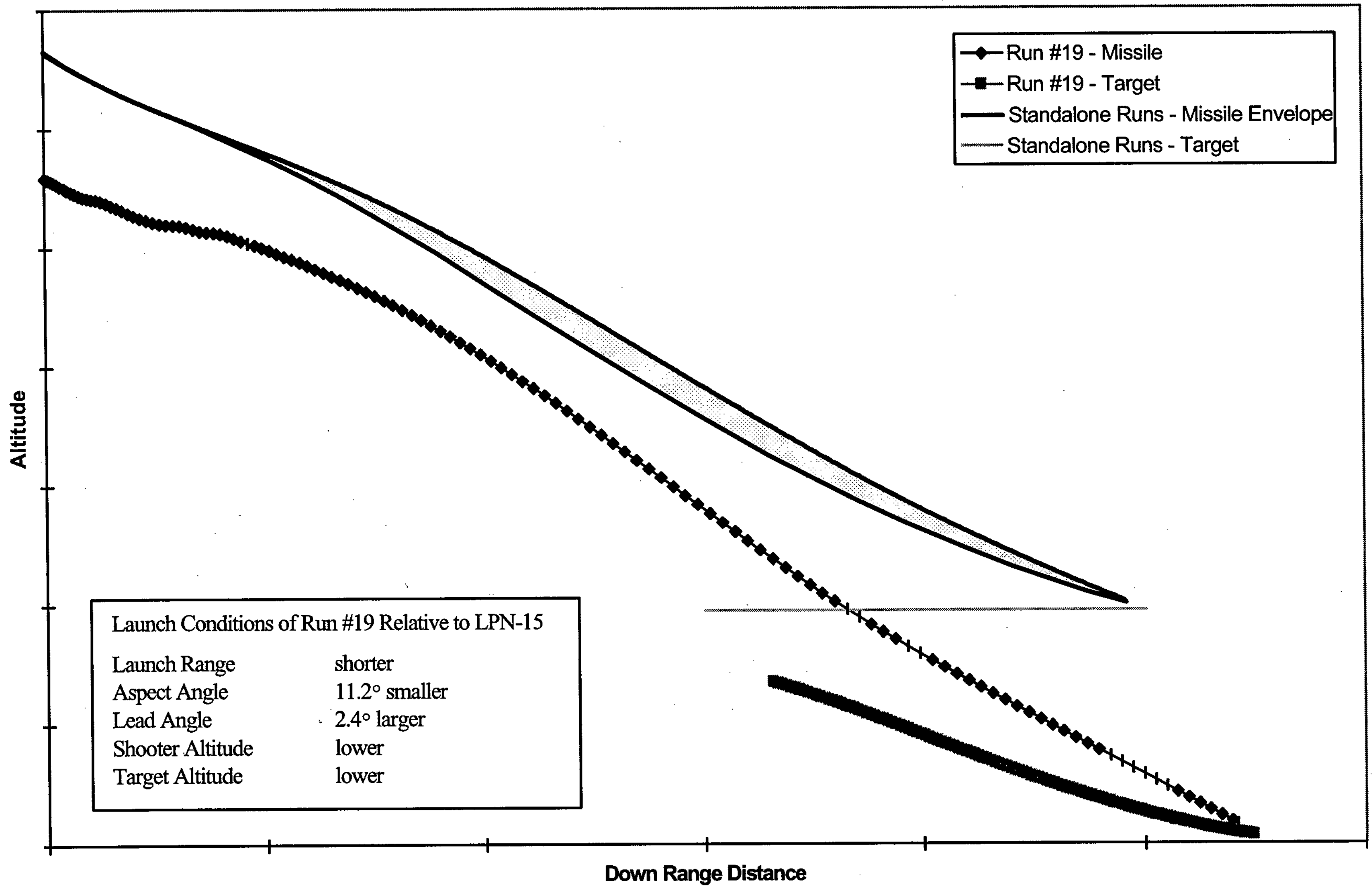


Figure 4.1.2.3-12c. Missile Flyout for Run #19 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #2

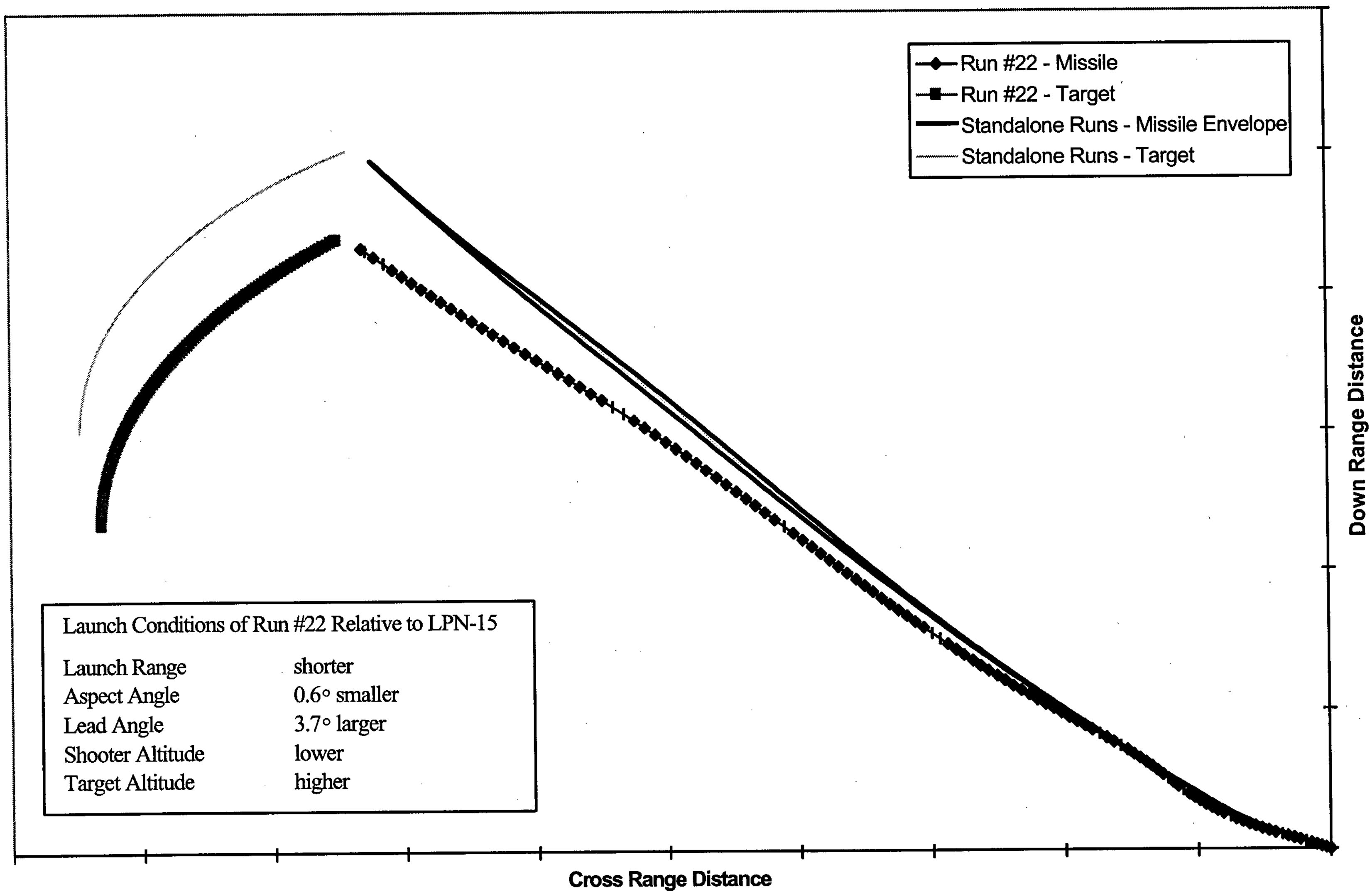


Figure 4.1.2.3-13a. Missile Flyout for Run #22 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - "God's-Eye" View

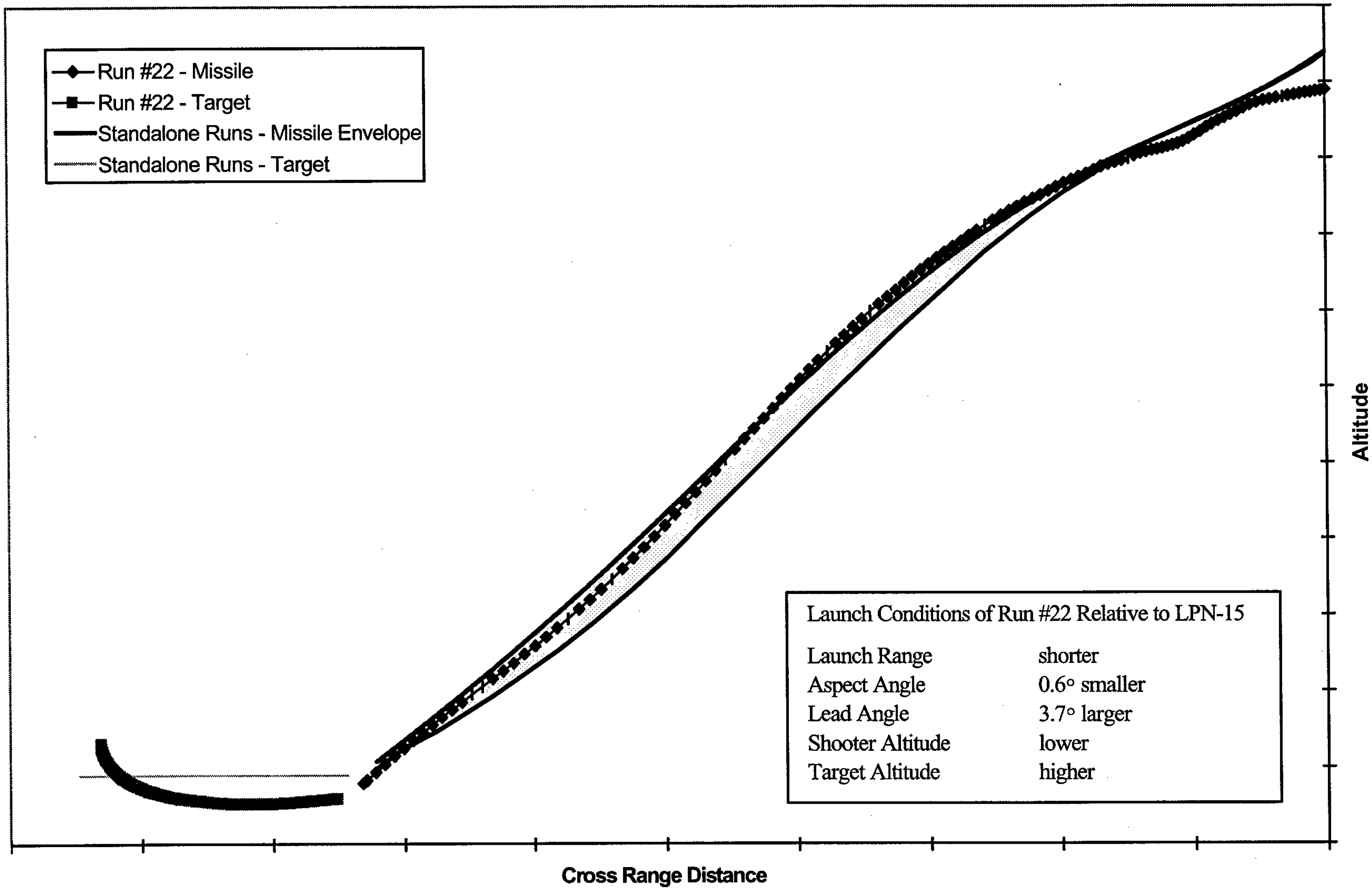


Figure 4.1.2.3-13b. Missile Flyout for Run #22 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #1

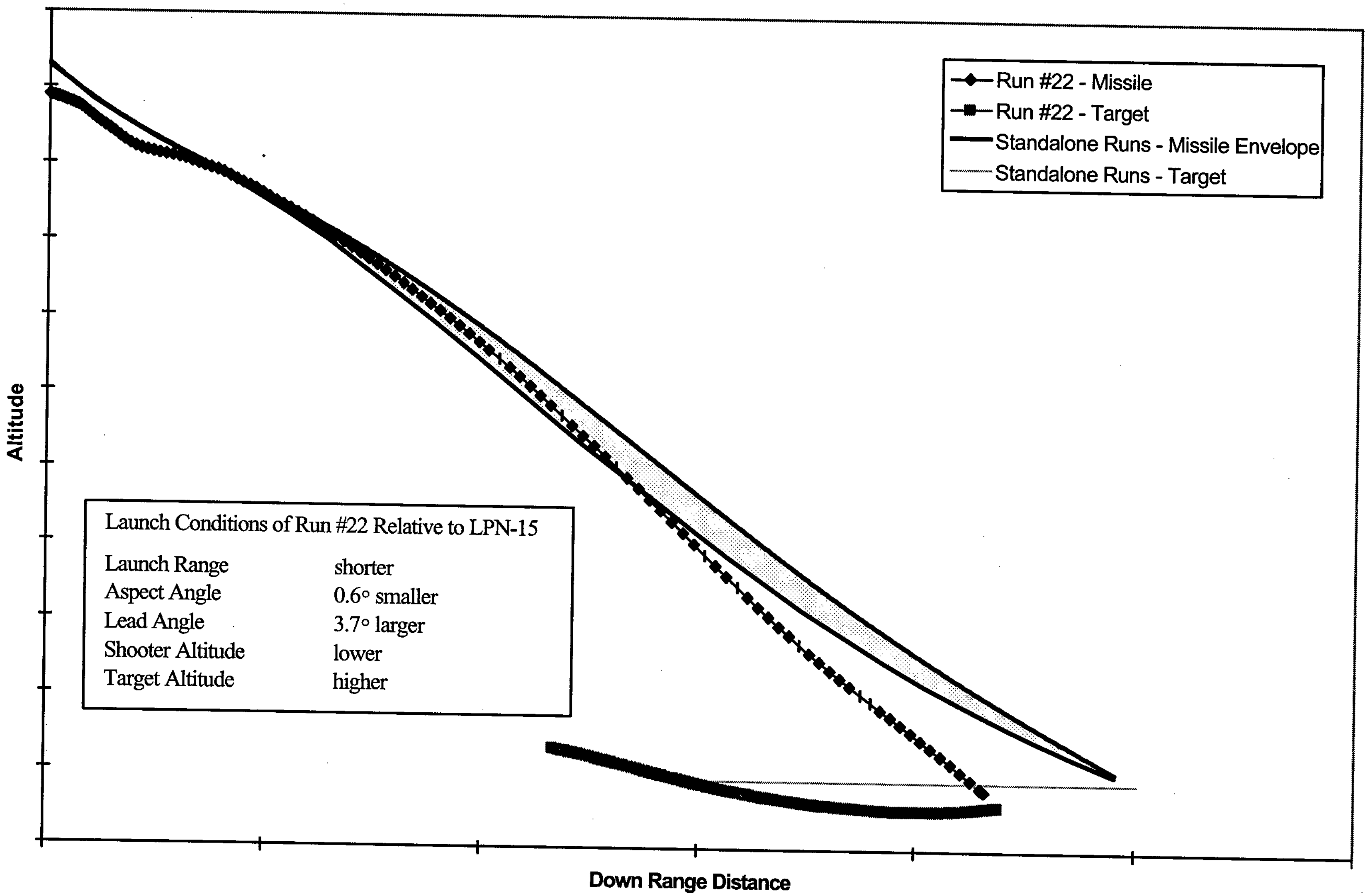


Figure 4.1.2.3-13c. Missile Flyout for Run #22 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact LPN-15 launch conditions) - Side View #2

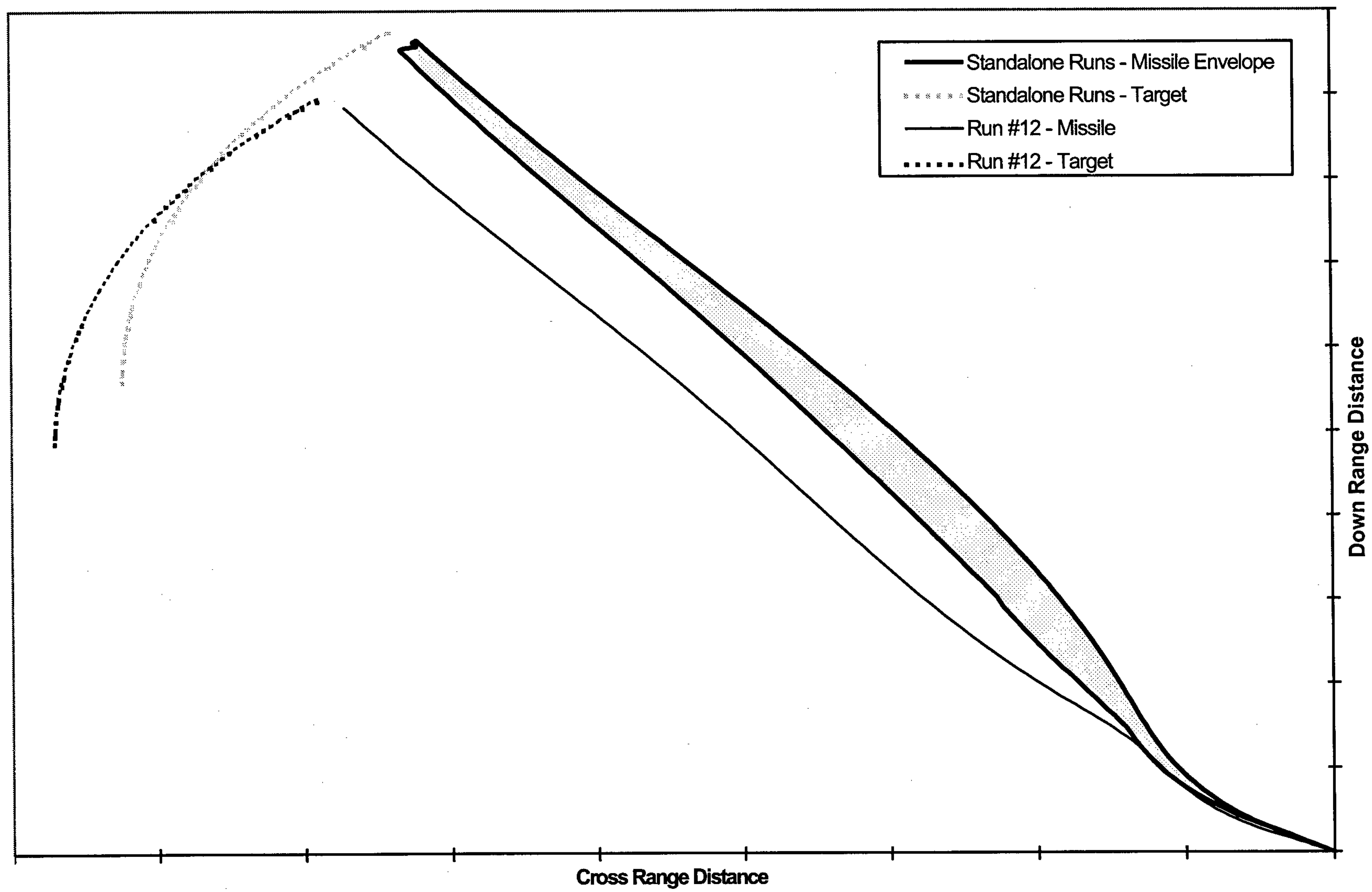


Figure 4.1.2.3-14. Missile Flyout for Run #12 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact Run #12 launch conditions) - "God's-Eye" View

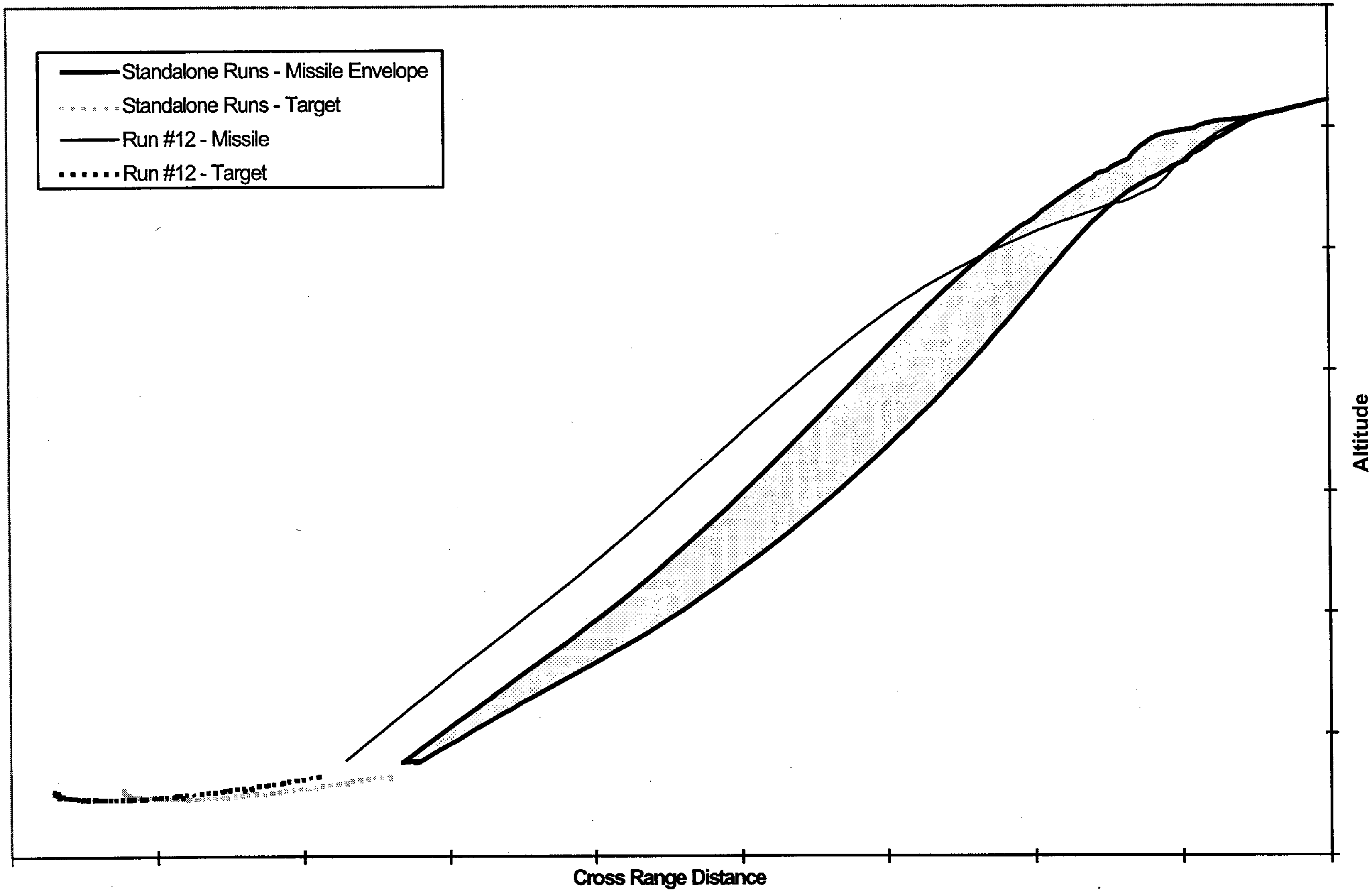


Figure 4.1.2.3-15. Missile Flyout for Run #12 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact Run #12 launch conditions) - Side View #1

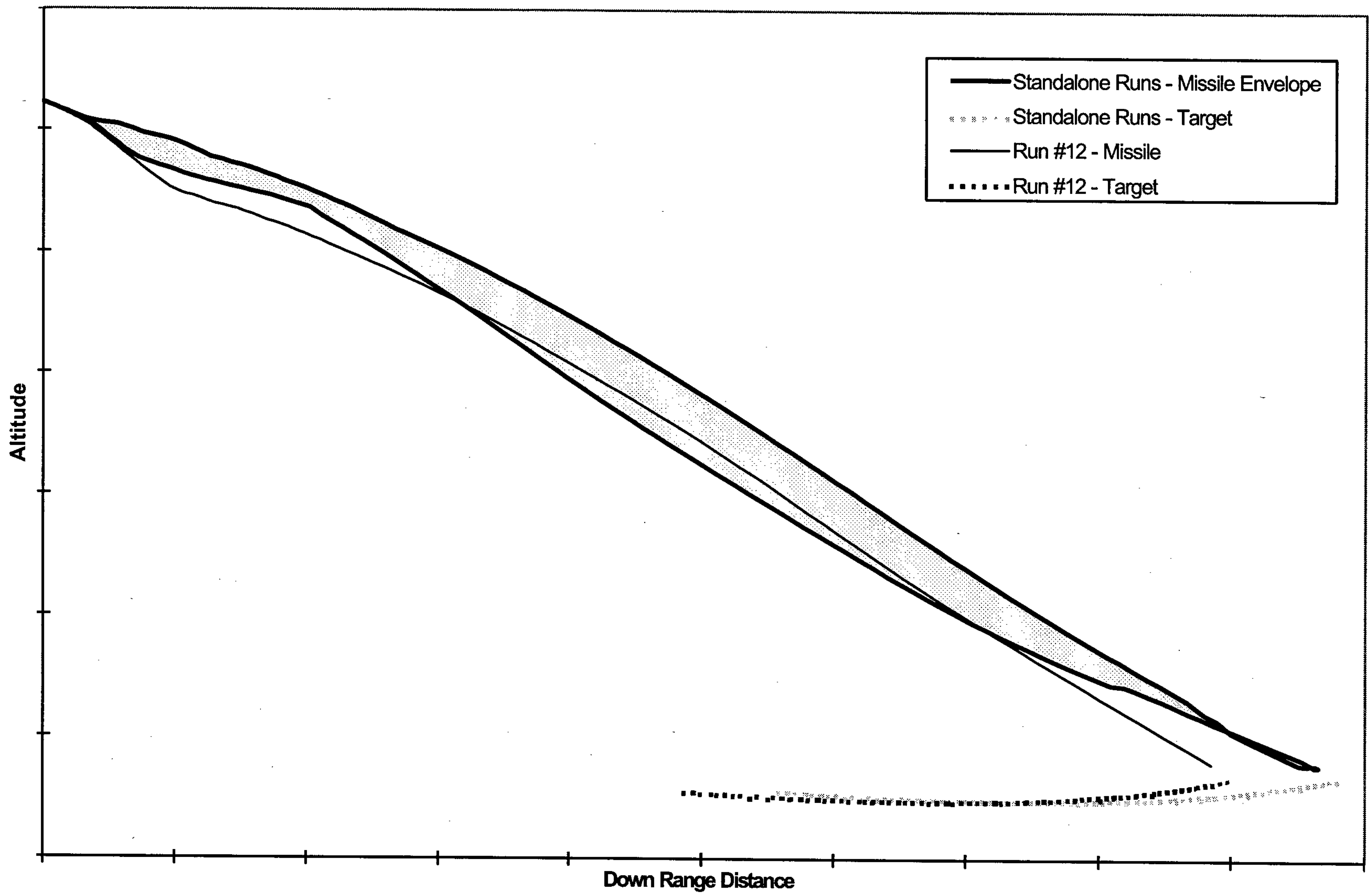


Figure 4.1.2.3-16. Missile Flyout for Run #12 (11/19/96) Compared to Envelope of SIMLAB Standalone Runs (using exact Run #12 launch conditions) - Side View #2

4.1.2.4 Validation Summary

The results for the validation objective are summarized as follows:

- The SIMLAB standalone simulation of the missile flyout for the LPN-15 conditions was valid.
- A problem with the missile lofting above the shooter altitude was observed during the Mission Rehearsal and the V&V Mission. The lofting problem was fixed for the Parametric Study Mission.
- The planned quantitative validation technique based on comparing the missile flyouts from the linked runs to the envelopes resulting from Monte Carlo sampling of launch conditions had to be abandoned. It was incapable of identifying many of the invalid lofting missile trajectories.
- The validation approach was modified to include both qualitative and quantitative validation methods.
  - The qualitative method compared the shape of the missile trajectory to that for LPN-15 by looking for the following qualitative features:
    - An initial straight "safe-separation" segment.
    - A distinct guidance correction at the end of the "safe-separation" segment.
    - Continual and smooth closing on the target with no gain in missile altitude.
    - This method identified the missile lofting as an invalid flyout.
  - The quantitative method involved SIMLAB standalone runs using the linked result in which the launch conditions most closely matched those of LPN-15.
    - On each trial, the exact launch conditions of the best linkedrun were used.
    - The results of 20 missile flyouts were used to define an envelope of valid flyouts.
    - The flyout of the linked run was validated by comparing it to the envelope to determine if the missile trajectory was entirely within the envelope.
- Applying the qualitative method to the Parametric Study Mission V2 runs showed that the missile flyouts were valid for the target representation in the SIMLAB reference frame.
- Applying the quantitative method to the best of the Parametric Study Mission V2 runs showed that the missile flyouts from the linked runs were invalid because the target representation in the SIMLAB reference frame was in error.
  - Target representation errors resulted in the missile flying against a significantly different target trajectory than was generated by the WSIC.
  - Errors in initializing the target and missile in the SIMLAB reference frame were not discovered until after the linked runs were completed and have since been fixed.
    - During the missions, quick-look qualit ative validation of the SIMLAB results was performed by using plots from the SIMLAB simulation. These plots were successful in identifying the missile lofting and latitude divergence problems, but not the target initialization error. The latter was not discovered until the missile and target trajectories were plotted from PDU data after the testing was over.
  - Validity of the missile flyout can be further improved by more accurate SIMLAB integration of the target velocity to determine target position.

4.2 Test Objective 2: Assess utility of LSP ADS configuration for parametric studies

This objective evaluates a potential benefit of the LSP ADS configuration to AIM-9 testing: the ability to conduct parametric studies. The assessment addressed two questions: (1) can valid parametric studies involving countermeasures (CM) effectiveness be conducted with this ADS configuration? (2) if so, is there utility in using this ADS configuration for such studies? The first question was addressed by evaluating the ability to repeat a given scenario with either no changes or with a single parameter varying. The second question was addressed by evaluating the cost and efficiency of executing the parametric studies using the LSP ADS configuration.

4.2.1 Parametric Study Test Method

The Parametric Study Mission was designed to accomplish this test objective and was to utilize variations in the live fire test baseline, LPN-15. In this mission, the engagement was to begin with the same initial conditions as in LPN-15 (Fig. 4.1.2.1-1). The difference was to be that the target would now receive a missile warning detection cue (either at or after launch) and employ countermeasures based on that cue (rather than at a preset time, as in LPN-15). The countermeasures were to always involve ejection of flares, but could also include evasive maneuvers.

Features of the Parametric Study Mission were to be as follows:

- This mission was to utilize the same initial engagement geometry as the V&V Mission. The V&V profile was to be modified by changing the flare release time and by executing an evasive maneuver (in some profiles) after the missile was launched. The values for the flare release and evasive maneuver times were to be 0, 2, or 4 seconds after missile launch.

- The mission was to begin with repetitions of the verification and the validation passes from the V&V Mission to ensure the test configuration was working properly. Note that the V&V Mission did not utilize warning cues to dispense the flares (they were dispensed at a preset time during the engagement).

- Half of the runs for each profile were to be manually flown by the simulator pilots on the first day of the mission. The manual trial for each profile which best matched the planned profile was to be automatically replayed on the second day of the mission for the remaining runs. The automatic replay runs were executed as follows:

  -- The shooter and target simulators replayed their respective recorded output from one of the manual linked runs. Each aircraft simulator was started manually by local operators when directed by the test controller. In this mode there were no pilots flying or controlling the shooter and target simulators (except for manual trigger squeeze by the shooter and manual flare release). The SIMLAB (missile) was driven in each run by inputs from the shooter and target. Control of shooter and target trajectories and timed events (except for trigger squeeze and flare release) were all embedded in the playback data.

- The countermeasu res (flare release and target maneuver) were to be executed when the warning cue was received by the target.

- Automatic flare release was to initiated by automatic transmission of a Fire (Flare) PDU from the WSIC to the SIMLAB. Upon receipt of this PDU, the SIMLAB flare simulation was to be started.

- In all passes, the target aircraft was already in a 3.6 g turn at missile launch (see Fig. 4.1.2.1-1). In the runs involving the evasive maneuver, the target pilot was to increase the turn rate by at least 3.4 g to 7 g, or more, upon receipt of the warning cue.

4.2.2 Parametric Study Analysis Method

Data from the manual runs performed on the first day of the Parametric Study Mission were analyzed to determine which run best achieved each of the desired profiles. Criteria for this determination were: (1) smallest differences between initial launch conditions achieved in the run and those for LPN-15, (2) smallest differences between target profile (position, velocity, and acceleration versus time) achieved in the run and the desired profile, and (3) smallest difference between flare release time achieved in the run and the desired value. The differences needed for the selection were computed as follows:

- Initial launch condition differences
  -- Each launch condition parameter, as determined by the SIMLAB missile simulation, was compared to the corresponding parameter from LPN-15.
  -- According to the LSP TAP, the percent difference between the SIMLAB value and the LPN-15 value was to be computed as (the desired value is the LPN-15 value in this case):

$$\text{Percent Difference} = \left|\frac{(\text{Actual Value}) - (\text{Desired Value})}{\text{Desired Value}}\right| \tag{3}$$

  -- However, Equation 3 was modified to simply compute the difference. This was done because the raw differences could be compared directly to the shot box tolerances and because some of the parameters (e.g. altitudes) had large values and the percent differences would have been arbitrarily small. Hence, the following equation was used instead of Equation 3:

$$\text{Difference} = (\text{Actual Value}) - (\text{Desired Value}) \tag{4}$$

- Target profile differences during missile flyout
  -- Five profiles were to be separately compared: x-position vs. time, y-position vs. time, z-position vs. time, velocity magnitude vs. time, and acceleration magnitude vs. time.
    --- This was modified to only compare altitude vs. time, velocity magnitude vs. time, and acceleration vs. time. This was changed because differences in the target

profile during missile flyout primarily depended on differences in launch conditions (only the target location and orientation relative to the shooter and missile mattered during the missile flyout, not the target's absolute location) and because the key features the desired target trajectory were constant altitude, velocity, and acceleration.

-- The percent difference between the actual value achieved on the run and the desired value was to be computed at each 0.1 second increment of time using Equation 3 (data were to be interpolated, as needed, to determine the values at each time increment).
  --- This was modified to only compute the difference, not the percent difference, using Equation 4.
  --- Rather than interpolate data to determine values at 0.1 second time increments, data from the target entity state PDUs logged at the SIMLAB DIS logger were averaged during the missile flyout. Although the PDUs were not logged at constant rates, this approach provided sufficient accuracy for determining average differences.

- Flare release time difference
  -- The percent difference between the actual value achieved o n the run and the desired value was to be computed using Equation 3.
    --- This was modified to only compute the difference, not the percent difference, using Equation 4.

Data from the automatic replay runs were analyzed to determine the run-to-run variations for each profile. Differences for initial launch conditions, target profiles, and flare release time were computed as above using the data from the replay runs of each profile. The mean and standard deviation of the differences for all runs of each profile were computed.

The average number of runs per hour for the entire Parametric Study Mission was computed using the total number of runs executed divided by the total time that the LSP configuration was operational. Statistics for each parametric variation (i.e., profile) were also computed as follows:

- The set up time for each profile was determined by subtracting the time when set up was started from the time when set up was completed. The set up time was separately computed for manual runs (Day 1 of the mission) and automatic runs (Day 2 of the mission).
- The runs per hour for each profile was determined by dividing the total number of runs by the total time to execute the runs. The latter was determined by subtracting the time when the first run of the profile was begun from the time when the last run of the profile was completed. The runs per hour was separately computed for manual runs and automatic runs.

The cost per run was computed by dividing the total cost of the Parametric Study Mission by the total number of valid runs executed (a valid run was one which produced valid SIMLAB results).

4.2.3 Parametric Study Results

The Parametric Study Mission test matrix, as given in the LSP TAP, could not be executed. Due to invalid missile flyouts in the V&V Mission (10/29/96), additional runs during the Parametric Study Mission (11/19/96) had to be devoted to V&V. Also, AIM-9 hardware problems at the SIMLAB prevented accomplishing all the planned runs for the Parametric Study Mission. In particular, none of the parametric runs in which the flares simulation was triggered by the WSIC were successfully completed. Rather, only the V2 profile (which replicated LPN-15) was successfully performed.

Because of these problems during the Parametric Study Mission, data for evaluating Test Objective 2 was taken from the Mission Rehearsal (8/27/96 and 8/28/96). There are several reasons for using these data:

- The rehearsal practiced execution of the V2 profile using both manual and automatic replay methods. As discussed below, this was the only testing period during which the automatic replay method was used.
- A relatively large number of runs were successfully completed, and the aircraft simulator pilots had the opportunity to learn their cues for reliably reproducing the LPN-15 launch conditions.
- Although the Mission Rehearsal only used the V1 and V2 profiles, the results were adequate for evaluating Test Objective 2. The objective was to evaluate differences between the actual and planned profile parameters using Equation 4, and this can be satisfied by using only a single planned profile (LPN-15), rather than a number of profiles.

The analysis results are given separately for the manual and the automatic replay methods.

4.2.3.1 Manual Runs Results

Launch Conditions. The launch conditions obtained in each successful V2 run (successful runs were those in which the missile was launched, even if the launch conditions were outside the shot box or the missile flyout was incomplete) were compared to those for LPN-15 and the differences were computed using Equation 4. The manual runs were executed over two days during the Mission Rehearsal, and results are given separately for each day. The resulting differences between the actual launch conditions and the LPN-15 values are given for each manual run in Figures 4.2.3.1-1 through 4.2.3.1-9 (NOTE: the trial numbers in these figures are consecutive for the runs selected and are not the same as the run numbers). These figures also indicate the shot box tolerances for each parameter and show a second degree polynomial fit to the data. The mean and standard deviations for the differences in each launch condition parameter are summarized in Table 4.2.3.1-1.

Table 4.2.3.1-1. Differences Between Actual and Desired Launch Conditions for Manual Runs.

Launch Parameter	Manual V2 Runs vs. LPN-15 (Day 1)	Manual V2 Runs vs. LPN-15 (Day 2)	Manual V2 Runs vs. LPN-15 (Total)

Shooter Velocity	11.05 ± 8.05 ft/s	23.18 ± 17.01 ft/s	15.09 ± 12.98 ft/s
Shooter Altitude	40.5 ± 134.1 ft	-3.03 ± 127.02 ft	26.0 ± 132.1 ft
Target Velocity	12.73 ± 4.45 ft/s	15.01 ± 5.30 ft/s	13.50 ± 4.82 ft/s
Target Altitude	76.6 ± 53.0 ft	56.1 ± 59.5 ft	69.8 ± 55.5 ft
Difference in Altitudes	-36.1 ± 151.7 ft	-59.1 ± 127.3 ft	-43.8 ± 143.1 ft
Launch Range	776.4 ± 292.4 ft	201.7 ± 426.4 ft	584.8 ± 435.2 ft
Target Aspect Angle	4.83 ± 2.56 deg	3.47 ± 1.96 deg	4.37 ± 2.44 deg
Lead Angle	-2.61 ± 1.58 deg	-2.95 ± 0.97 deg	-2.72 ± 1.41 deg
Flare Initiation Time	0.11 ± 1.58 sec	-0.13 ± 0.38 sec	0.03 ± 1.30 sec

The following conclusions are obtained from the figures and table:

- The distribution of results from the manual runs was significantly tighter than the shot box tolerances for all launch parameters. This may indicate that the shot box was wider than necessary, but does show good reproducibility of launch conditions by the pilots.
- In general, launch conditions from the manual runs showed bias. This was indicated by the mean values of the differences differing significantly from zero and by the means being significantly larger than the standard deviations (except for altitudes and flare initiation time). This may have been peculiar to the cues used by the pilots to achieve the desired launch conditions. Nevertheless, the mean and standard deviation values in Table 4.2.3.1-1 were all well within the shot box.
- The polynomial fits to the data points in the figures show that most parameters did not display a definite trend toward near-zero differences. The exception was the flare initiation time. Part of the reason for this was that the pilot developed cues for the launch conditions during dry runs prior to the Mission Rehearsal, but the proper manual flare initiation time was determined by trial and error during the mission.
- Results for the individual parameters are as follows:
  - -- Velocities of the shooter and target showed comparable, small positive biases (~30% of upper shot box limit). Comparing Figures 4.2.3.1-1 and 4.2.3.1-3 shows that the target was better able to maintain about the same velocity on each run. This was because the target was executing a level constant velocity turn, but the shooter had to lower his nose to boresight on the target at launch. This caused the shooter to lose altitude and gain velocity prior to launch with more run-to-run velocity variations. The inability of the target pilot to execute a perfectly level turn contributed to his run-to-run velocity variations.
  - -- The shooter altitude was the only aircraft-related launch condition that had a mean value smaller than the standard deviation. This indicates essentially no bias in this parameter. Note the relatively large run-to-run variations caused by the shooter losing altitude at launch, as discussed above.
  - -- The target altitude, like the target velocity, showed a small positive bias (~14% of upper shot box limit). The run-to-run variations in the target altitude are significantly

smaller that for the shooter altitude. This is to be expected, since the target was attempting to execute a flat turn while the shooter was losing altitude.

-- The difference between the shooter and target altitudes is given because only the altitude difference really mattered for the engagement. Variations in the altitude difference were dominated by the shooter altitude variations.
-- The launch range displayed a bias toward longer ranges than the LPN-15 value, although the trend in the second day data was toward the LPN-15 value. Note that 2 of the 48 trials (~4%) exceeded the upper shot box limit. The shooter was closing on the target prior to launch, and the start of the engagement had to be set up at a range longer than the LPN-15 launch range in order to be able to achieve the LPN-15 value at launch. This bias shows that the shooter was launching the missile too early for this parameter, in general.
-- The target aspect angle displayed a bias toward larger angles than the LPN-15 value. The target was executing a right turn in front of the shooter prior to launch, so that the aspect angle was increasing with time. This bias shows that the shooter was launching the missile too late for this parameter, in general.
-- The lead angle displayed a bias toward lag angles (the desired LPN-15 value was 0 °). Note that 3 of the 48 trial (~6%) exceeded the lower shot box limit. The shooter turned at launch to boresight on the target, starting from a lag angle. This bias shows that the shooter was launching the missile too early for this parameter, in general.
-- The flare initiation time showed a mean value ve ry close to the LPN-15 value. After the sixth trial, the difference on each trial was ~1 second, or less.

These results support the conclusion that the manual method for replicating a given profile (LPN-15 in this case) resulted in very good run-to-run reproducibility of the launch conditions.

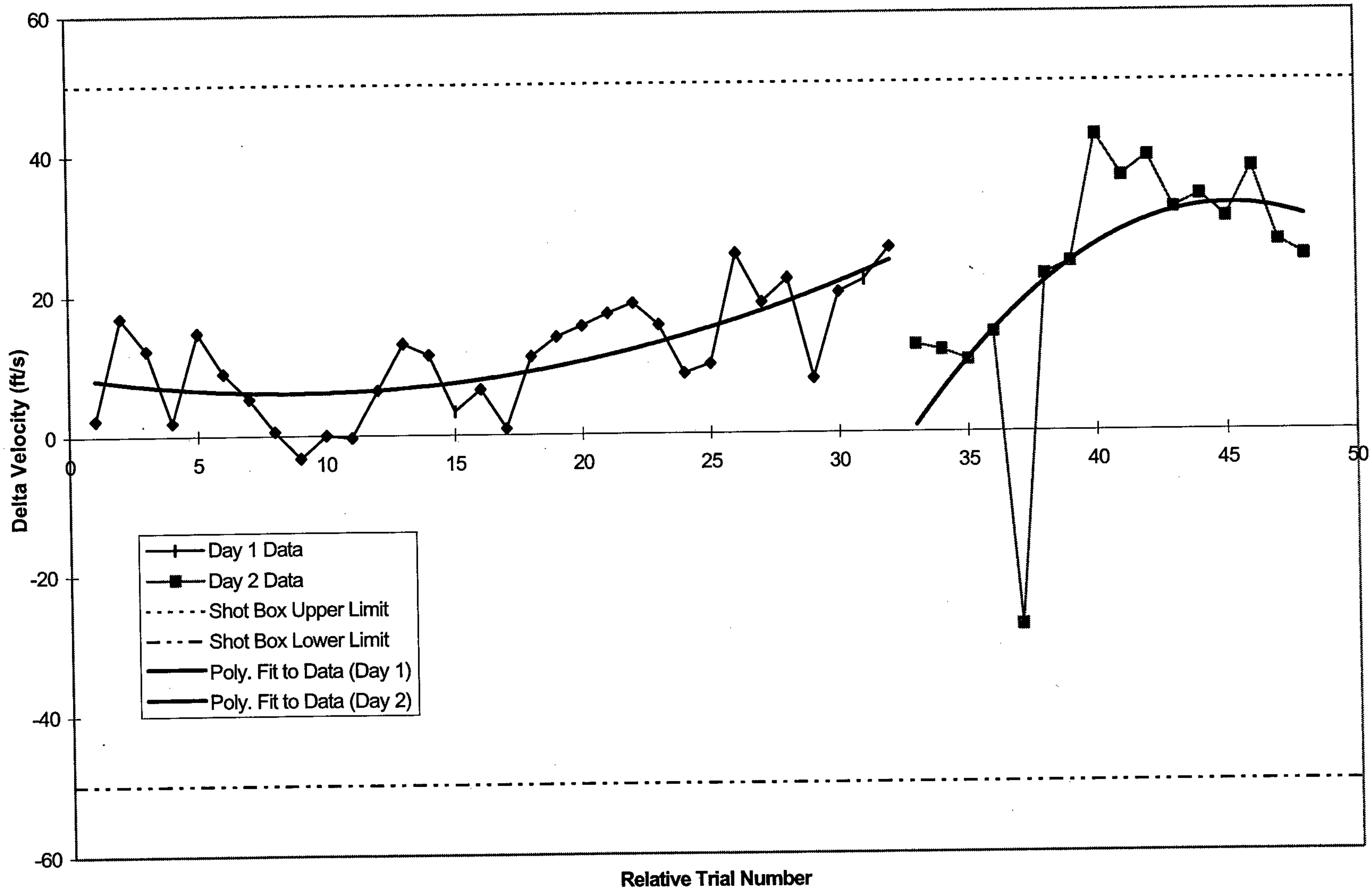


Figure 4.2.3.1-1. Shooter Velocity Relative to LPN-15 (Manual Trials)

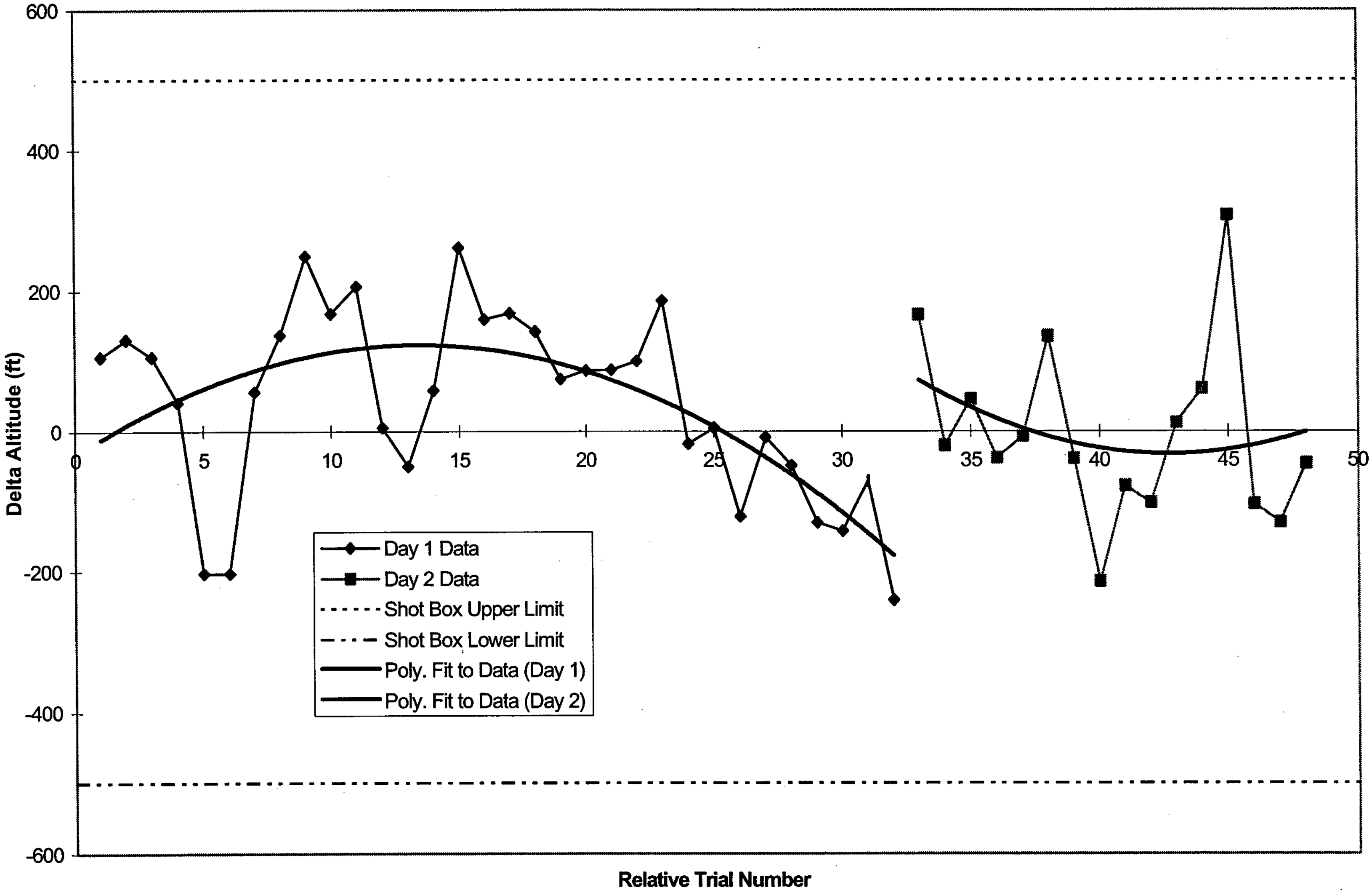


Figure 4.2.3.1-2. Shooter Altitude Relative to LPN-15 (Manual Trials)

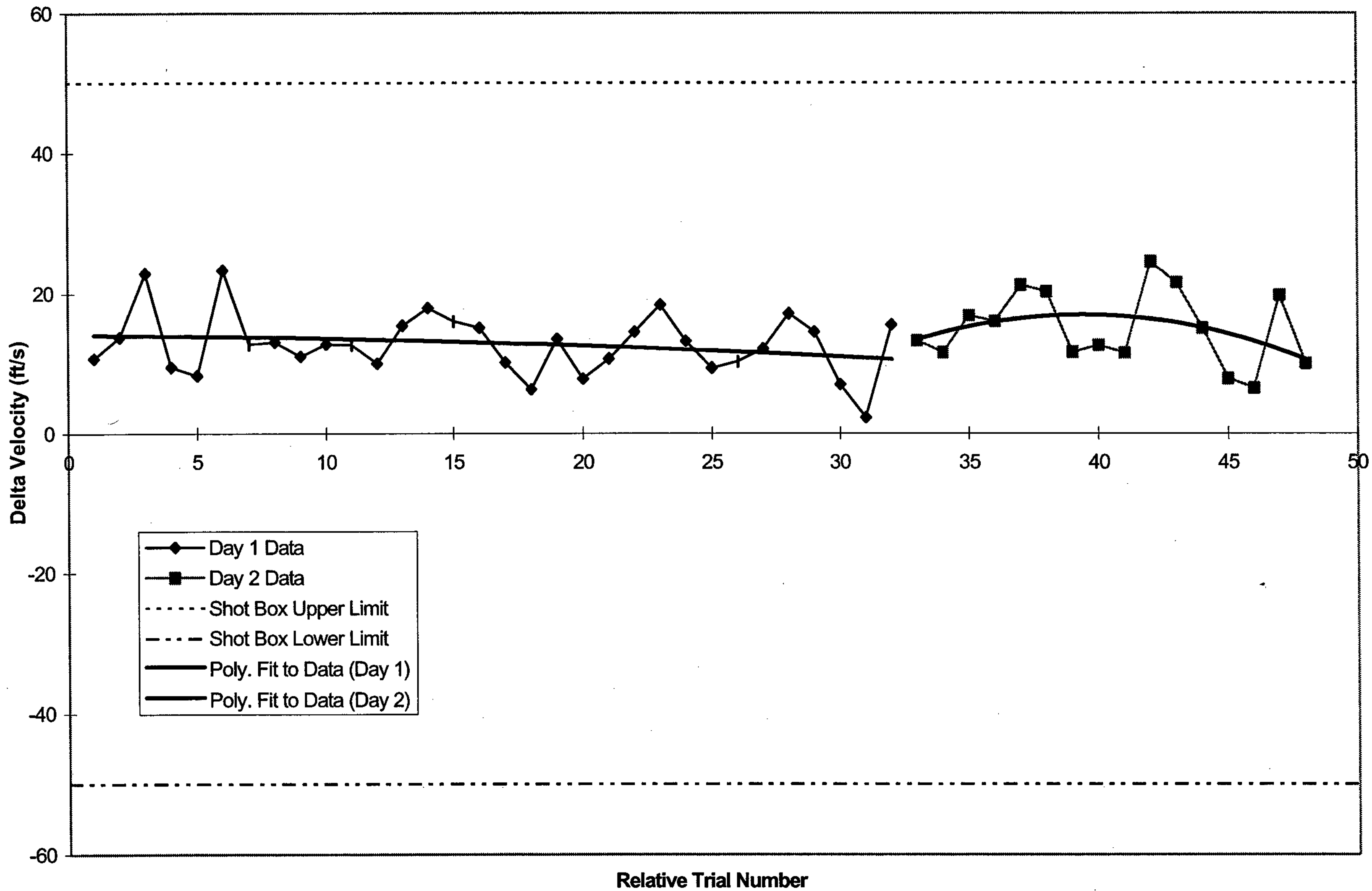


Figure 4.2.3.1-3. Target Velocity Relative to LPN-15 (Manual Trials)

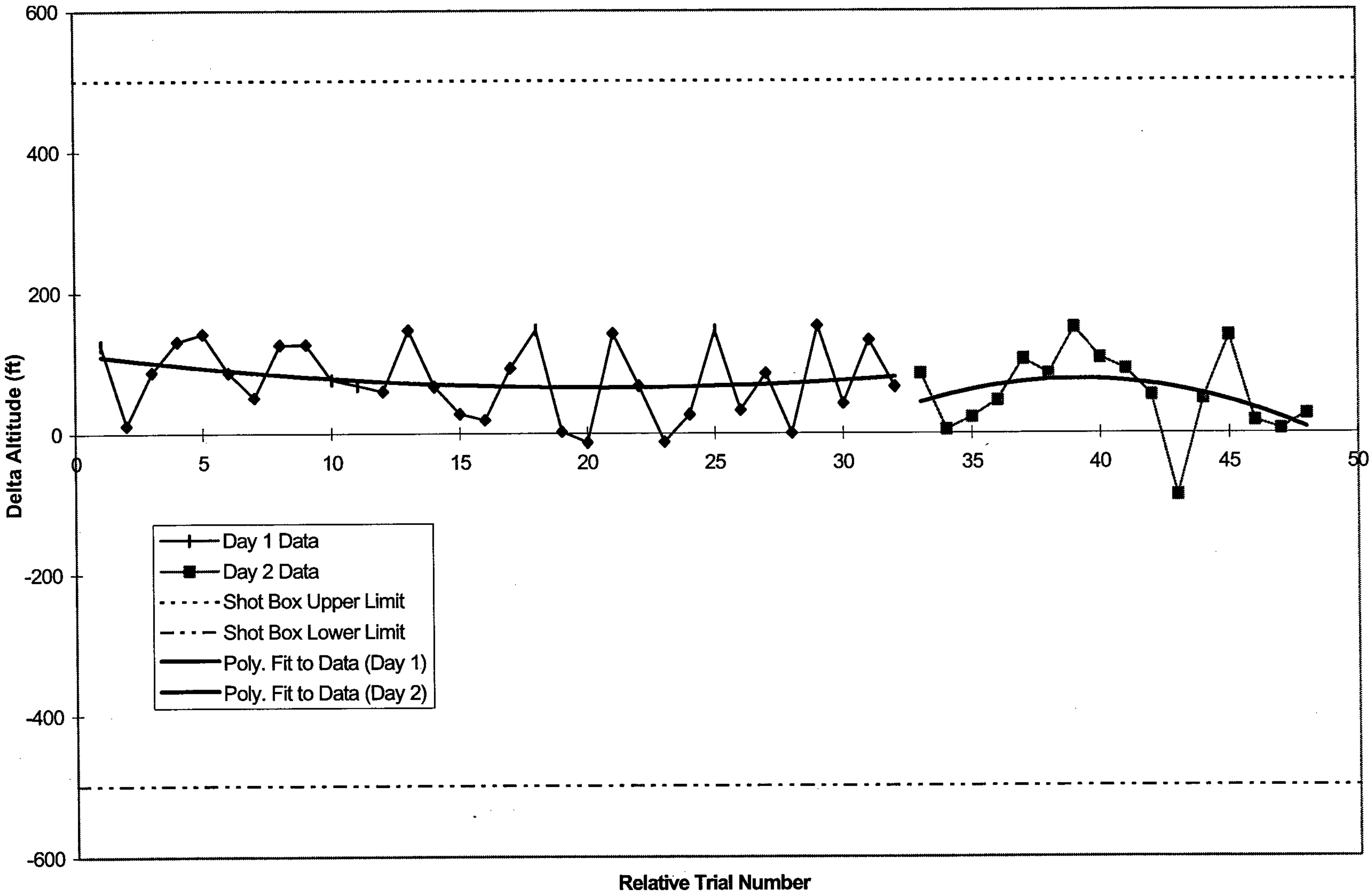


Figure 4.2.3.1-4. Target Altitude Relative to LPN-15 (Manual Trials)

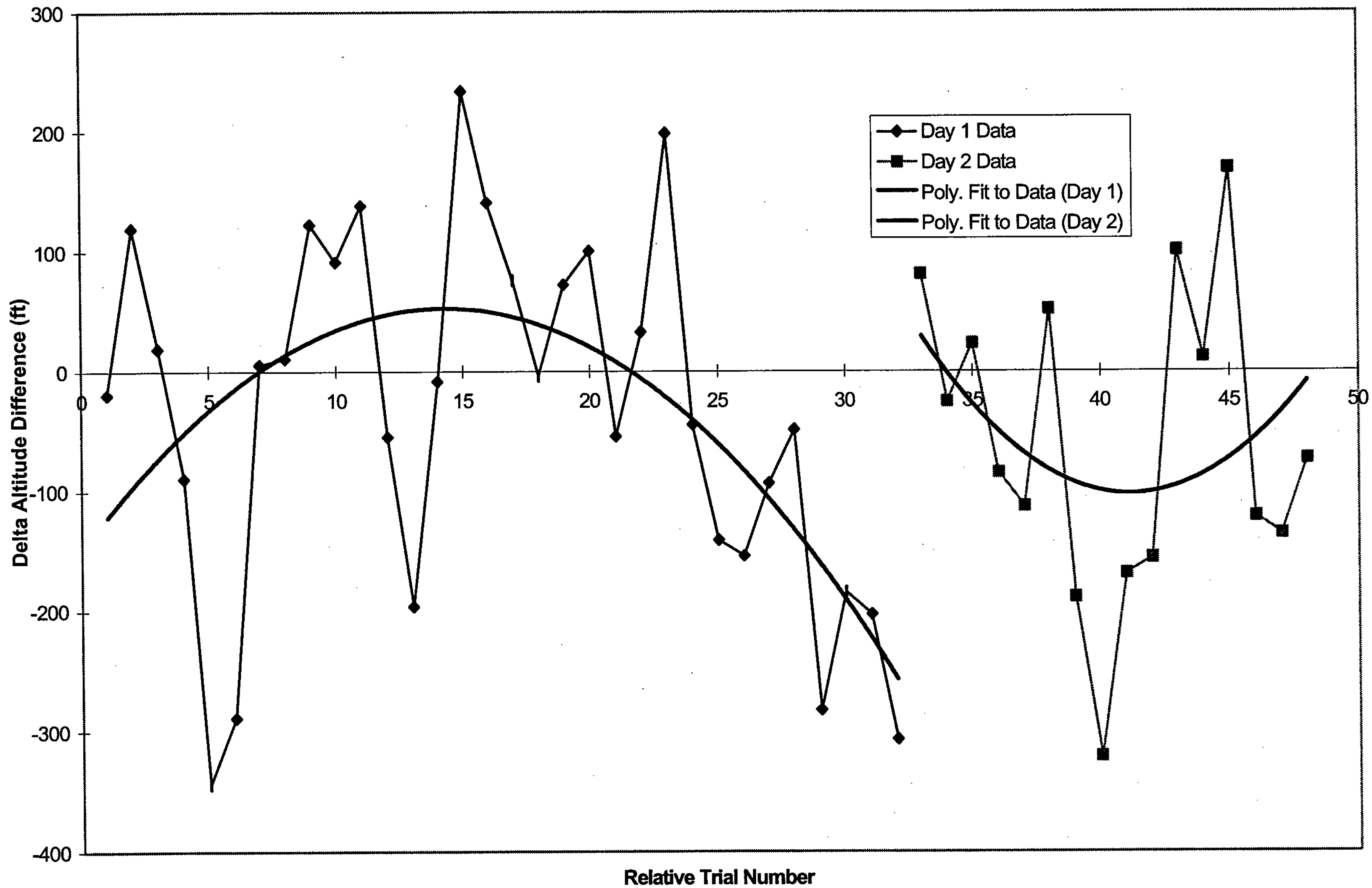


Figure 4.2.3.1-5. Shooter and Target Altitude Difference Relative to LPN-15 (Manual Trials)

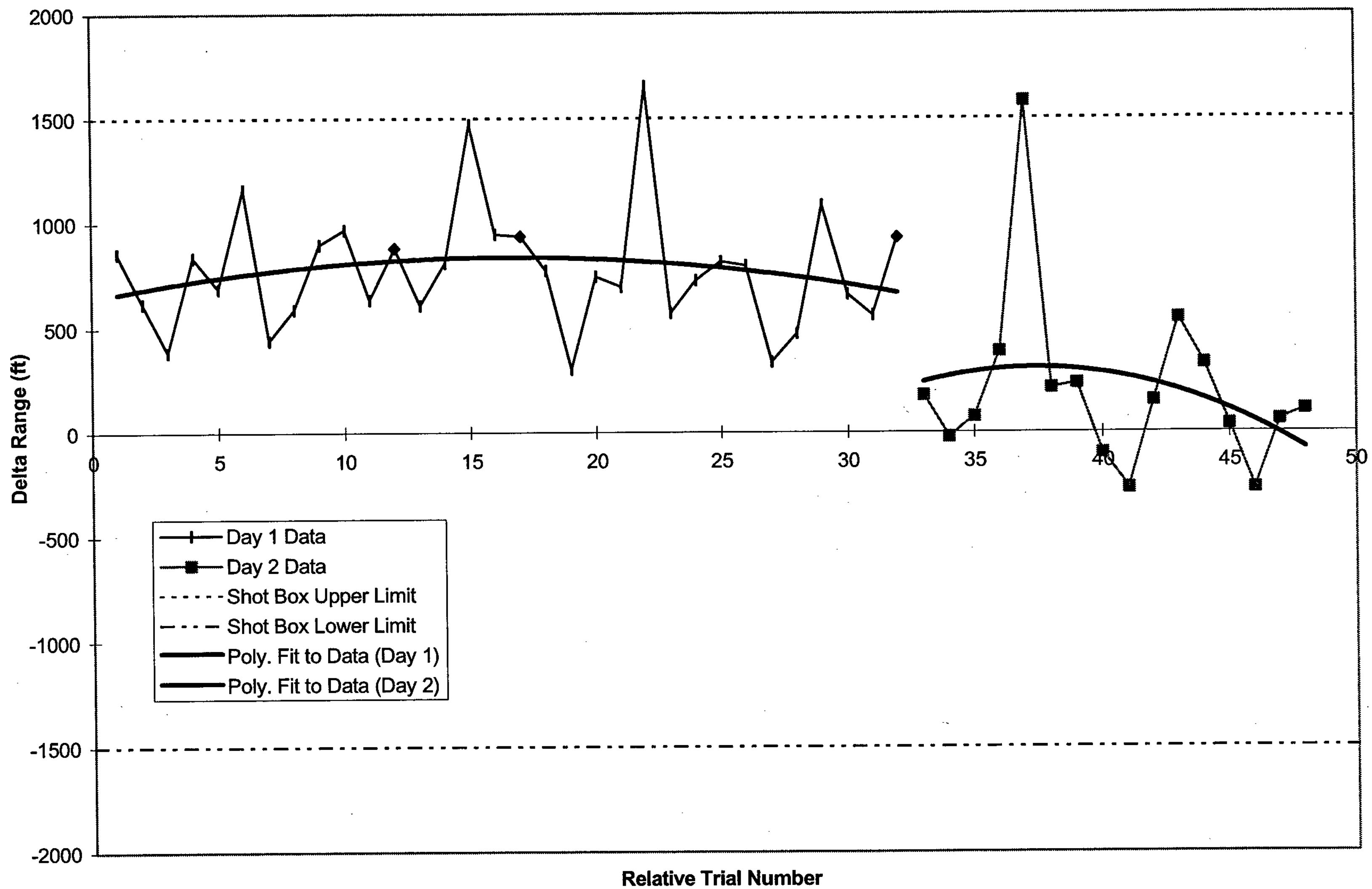


Figure 4.2.3.1-6. Launch Range Relative to LPN-15 (Manual Trials)

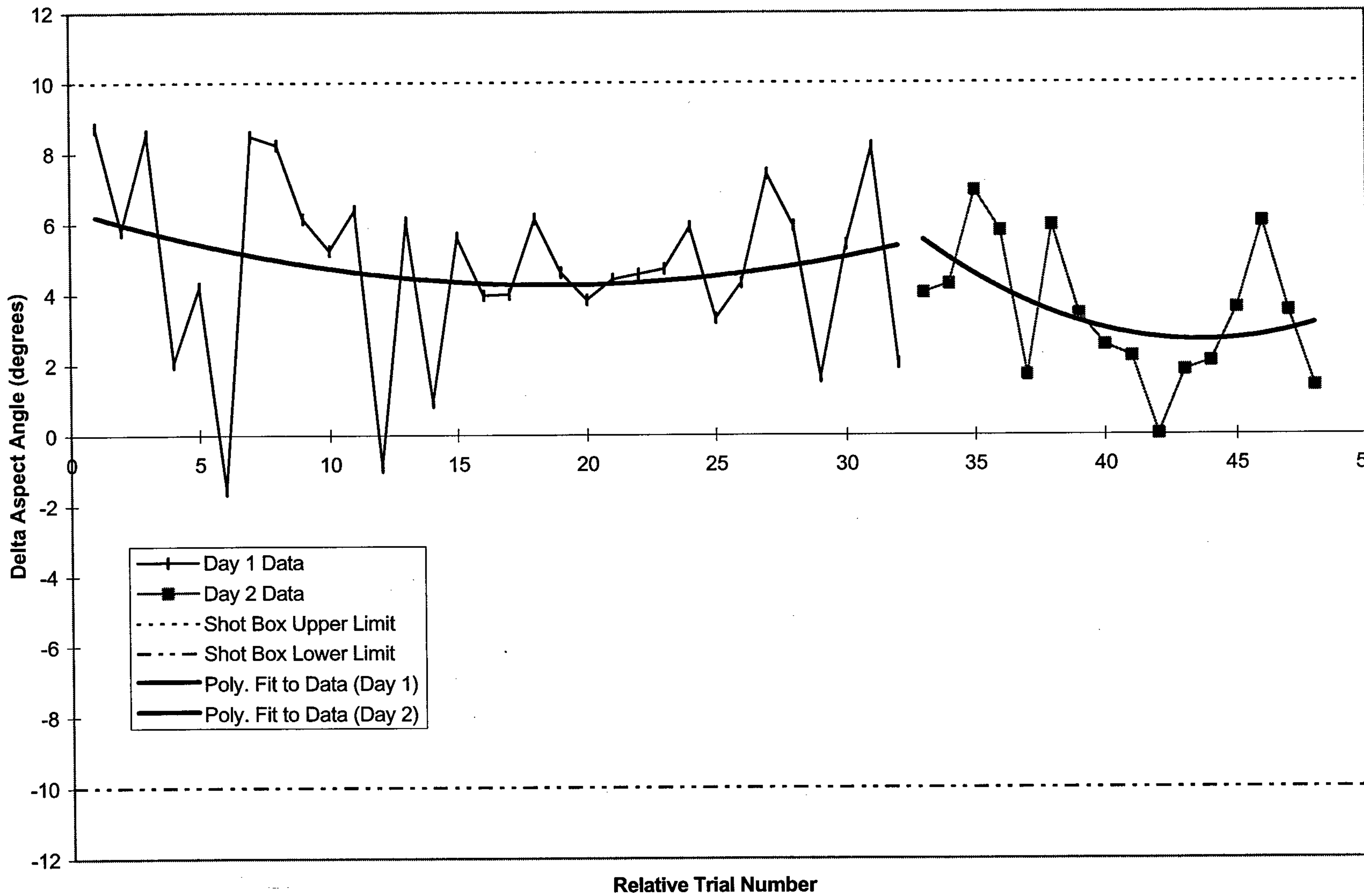


Figure 4.2.3.1-7. Target Aspect Angle Relative to LPN-15 (Manual Trials)

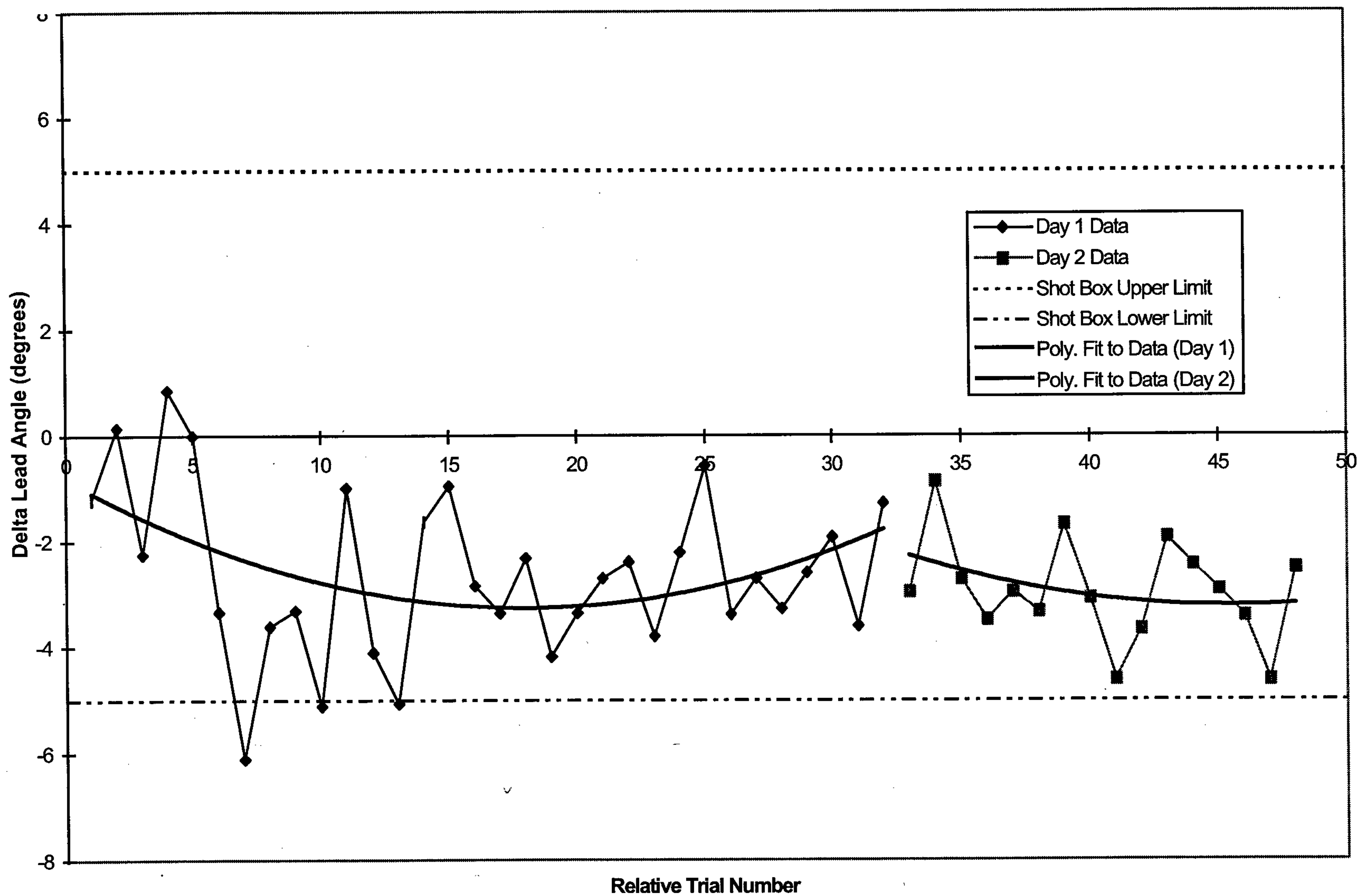


Figure 4.2.3.1-8. Lead Angle Relative to LPN-15 (Manual Trials)

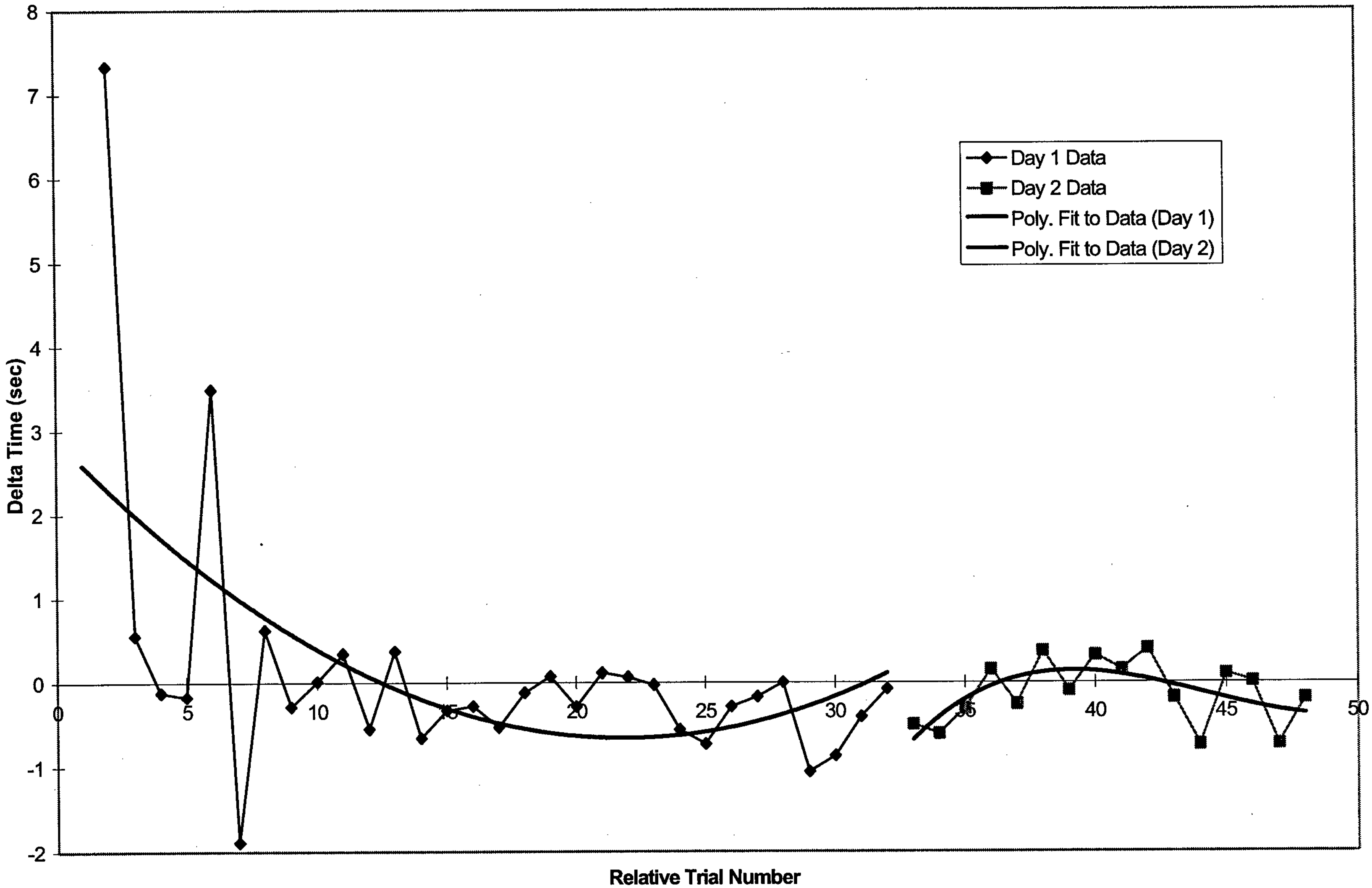


Figure 4.2.3.1-9. Flare Initiation Time Relative to LPN-15 (Manual Trials)

Target Profile During Missile Flyout . The entity state PDU data for the target profile obtained in each successful and complete V2 run (these runs were those in which the missile was launched and the missile flyout was complete, even if the launch conditions were outside the shot box) were compared to those for LPN-15 and the differences were computed for each target entity state PDU using Equation 4. The target parameters of interest were the target altitude (the target was to maintain a constant altitude of 10,387 ft during the missile flyout), the target velocity (the target was to maintain a constant velocity of 759 ft/s during the missile flyout), and the target acceleration (the target was to execute a constant 3.6 g right turn during the missile flyout). The mean and standard deviation values of the differences in these parameters are given in Table 4.2.3.1-2 (Day 1) and Table 4.2.3.1-3 (Day 2) for each manual trial analyzed (as before the trials are numbered consecutively, the trial number is not the same as the run number, and only the manual trials resulting in complete missile flyouts and data logging are shown).

Table 4.2.3.1-2. Target Parameters During Missile Flyout Relative to LPN-15 Values (Manual Trials, Day 1)

Trial #	Delta Altitude (ft)	Delta Velocity (ft/s)	Delta Acceleration (g)
1	246.2 ± 64.8	0.53 ± 1.11	-0.07 ± 0.15
2	32.7 ± 11.3	17.41 ± 1.75	0.25 ± 0.17
3	79.6 ±6.4	23.09 ± 4.31	-0.10 ± 0.09
6	118.1 ± 17.2	16.4 ± 2.79	-0.09 ± 0.06
8	161.2 ± 20.2	13.45 ± 0.81	0.06 ± 0.08
9	164.0 ± 22.3	10.51 ± 1.86	0.05 ± 0.15
14	62.4 ± 34.7	17.99 ± 0.91	-0.04 ± 0.07
15	45.8 ± 15.4	15.37 ± 0.51	0.05 ± 0.05
16	12.1 ± 22.8	9.34 ± 2.37	0 ± 0.19
17	56.2 ± 38.5	11.04 ± 1.91	-0.05 ± 0.17
18	102.7 ± 20.5	8.93 ± 1.24	-0.1 ± 0.15
19	55.9 ± 45.6	10.90 ± 1.11	-0.26 ± 0.14
20	-16.6 ± 26.3	2.15 ± 2.04	0.08 ± 0.03
21	66.9 ± 46.7	13.29 ± 0.81	0.04 ± 0.04
22	25.3 ± 26.3	15.82 ± 0.96	0.09 ± 0.10
23	44.8 ± 35.1	15.88 ± 1.17	-0.03 ± 0.08
24	62.6 ± 21.3	8.72 ± 1.78	-0.03 ± 0.06
25	149.7 ± 27.4	7.09 ± 1.67	-0.05 ± 0.07
26	99.0 ± 38.0	8.72 ± 0.71	-0.06 ± 0.01
27	5.0 ± 48.8	14.95 ± 1.12	-0.09 ± 0.07
28	-28.8 ± 20.6	17.46 ± 0.77	-0.24 ± 0.06
29	190.1 ± 16.2	13.56 ± 0.79	-0.01 ± 0.09
30	-25.4 ± 31.3	4.59 ± 1.06	-0.02 ± 0.05
31	80.2 ± 29.8	7.96 ± 1.88	0 ± 0.12
32	47.7 ± 6.8	14.47 ± 2.33	0 ± 0.18
Averages	73.5 ± 28.2	11.98 ± 1.51	-0.02 ± 0.10

Table 4.2.3.1-3. Target Parameters During Missile Flyout Relative to LPN-15 Values (Manual Trials, Day 2)

Trial #	Delta Altitude (ft)	Delta Velocity (ft/s)	Delta Acceleration (g)
33	36.4 ± 27.7	14.91 ± 0.47	-0.12 ± 0.07
34	48.5 ± 29.8	6.87 ± 1.85	-0.16 ± 0.16
35	-69.0 ± 39.2	18.95 ± 1.01	-0.05 ± 0.17
36	76.0 ± 10.4	14.51 ± 0.39	0.05 ± 0.09
38	0.6 ± 34.6	21.38 ± 1.00	-0.08 ± 0.04
39	183.2 ± 23.6	10.09 ± 0.35	0.04 ± 0.10
40	77.9 ± 23.0	14.27 ± 0.63	-0.03 ± 0.08
42	104.6 ± 31.9	23.10 ± 1.21	-0.27 ± 0.11
43	-137.2 ± 23.0	17.88 ± 2.39	-0.07 ± 0.17
44	58.5 ± 9.4	13.00 ± 0.68	0.02 ± 0.04
46	-20.1 ± 13.2	3.21 ± 3.06	0.09 ± 0.12
Averages	32.7 ± 24.2	14.38 ± 1.19	-0.05 ± 0.10
Averages Both Days	61.0 ± 27.0	12.71 ± 1.41	-0.03 ± 0.10

The mean values of the differences in the target parameters for each trial are plotted in Figures 4.2.3.1-10 through 4.2.3.1-12. These figures also show a second degree polynomial fit to the data. The following conclusions are obtained from the figures and tables:

- Comparing Tables 4.2.3.1-2 and 4.2.3.1-3 with Table 4.2.3.1-1 shows that the mean values of the differences in the target altitudes and velocities during the missile flyouts (61.0 ft and 12.71 ft/s) were comparable to the mean values for the corresponding parameters at launch (69.8 ft and 13.50 ft/s). Also, the spreads of the mean values during the missile flyouts (±75.8 ft and ±5.53 ft/s) were comparable to the spreads for the corresponding parameters at launch (±55.5 ft and ±4.82 ft/s). However, the variations in the target altitude and velocity during a single trial (±27.0 ft and ±1.41 ft/s) were significantly less than the spreads for the corresponding launch condition parameters. In other words, the target was able to maintain a relatively constant altitude and velocity during a trial, even though the mean values varied from run-to-run.
- The target was able to maintain a constant 3.6 g turn to within ±0.1 g. This was much better than the criterion given in the LSP TAP for acceptable trials (±0.5 g).

These results, along with those for the launch conditions, support the conclusion that the manual method for replicating a given profile (LPN-15 in this case) resulted in very good run-to-run reproducibility of the entire aircraft portion of the scenario. (Note that LPN-15 is a fairly dynamic scenario (target turning, shooter closing on target and descending), so that it was not possible for the pilots to precisely match all the LPN-15 conditions simultaneously.) Hence, the manual method is able to effectively support parametric studies.

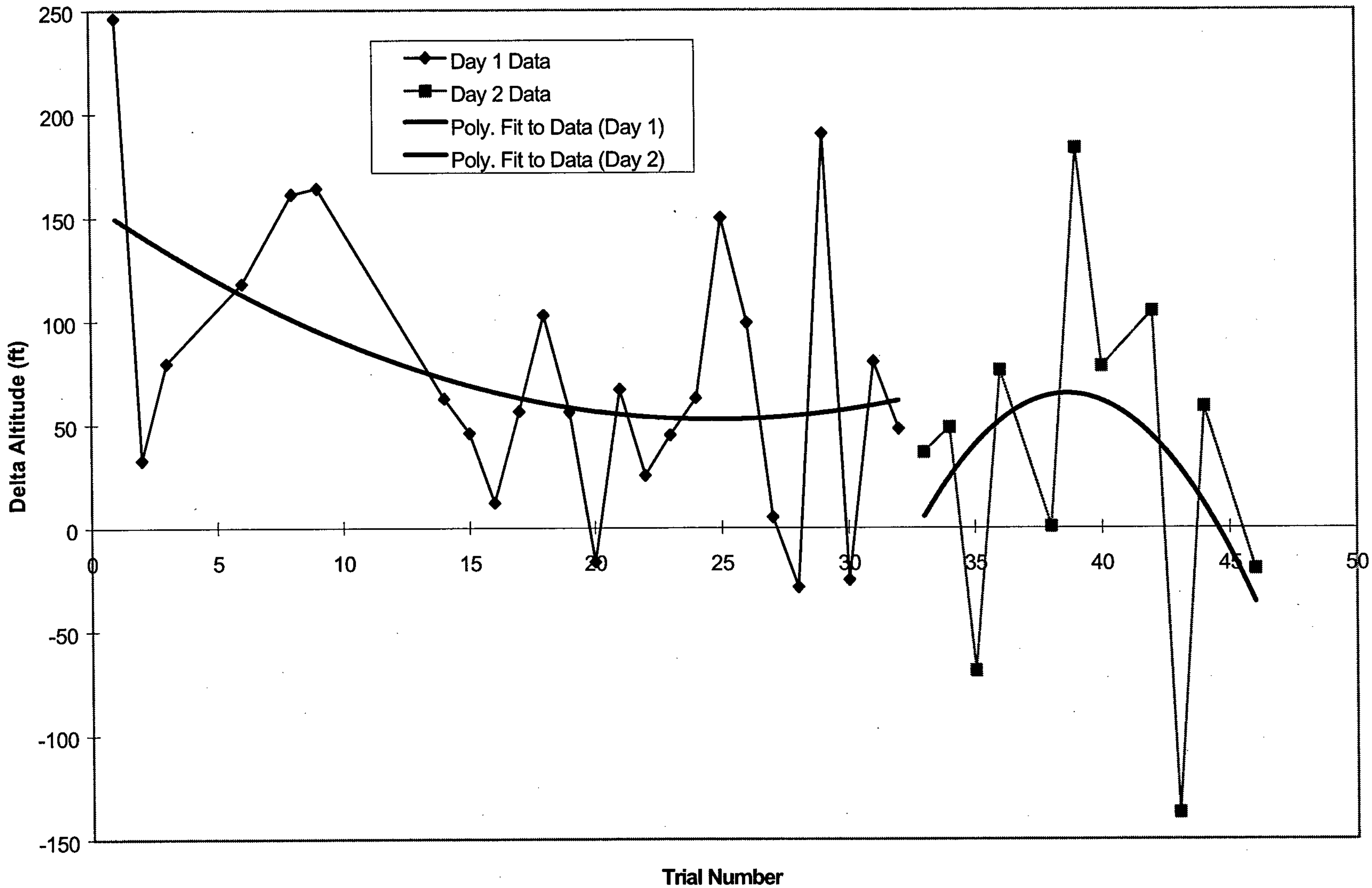


Figure 4.2.3.1-10. Mean Target Altitude During Missile Flyout Relative to LPN-15 Value (Manual Trials)

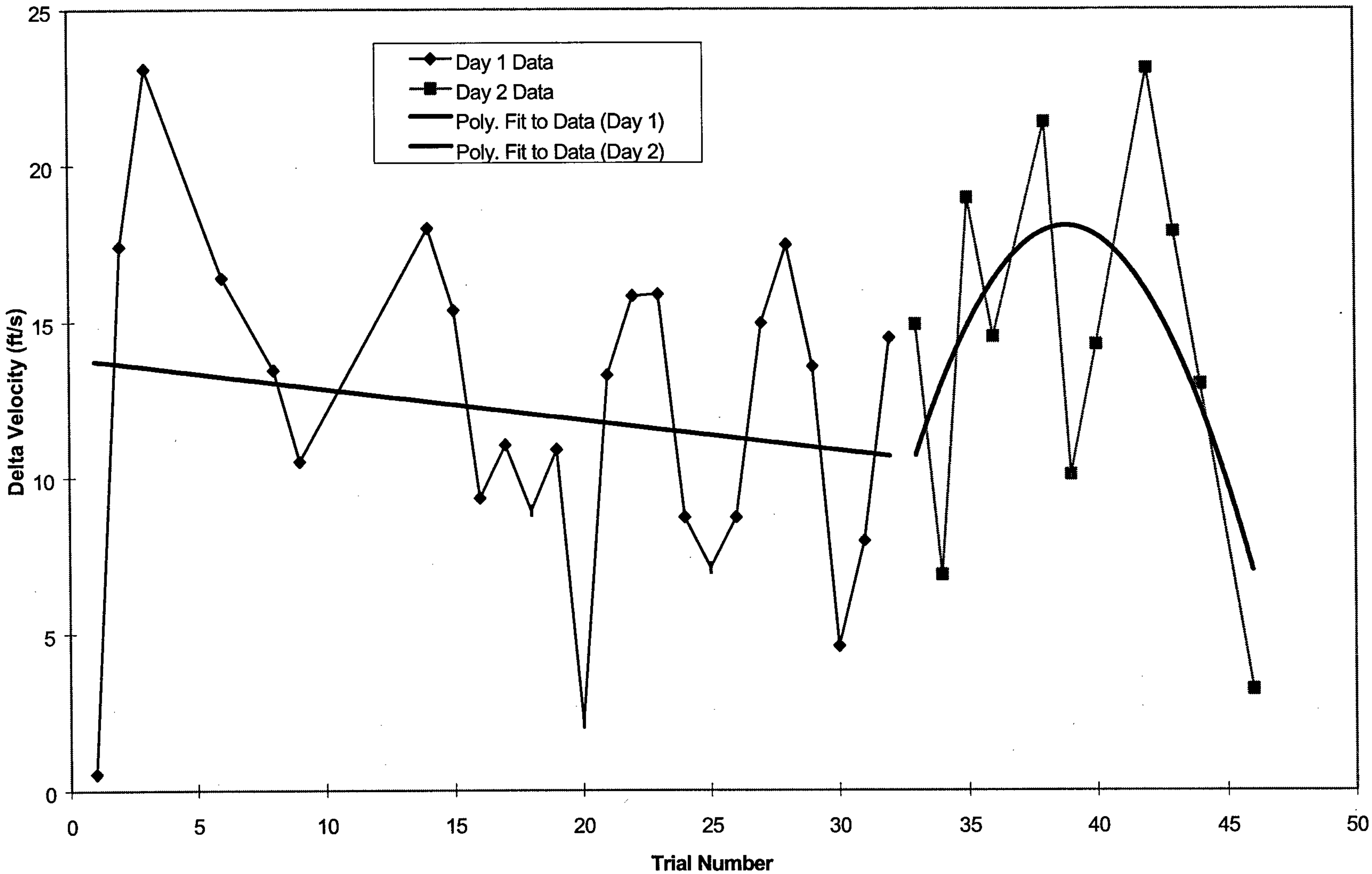


Figure 4.2.3.1-11. Mean Target Velocity During Missile Flyout Relative to LPN-15 Value (Manual Trials)

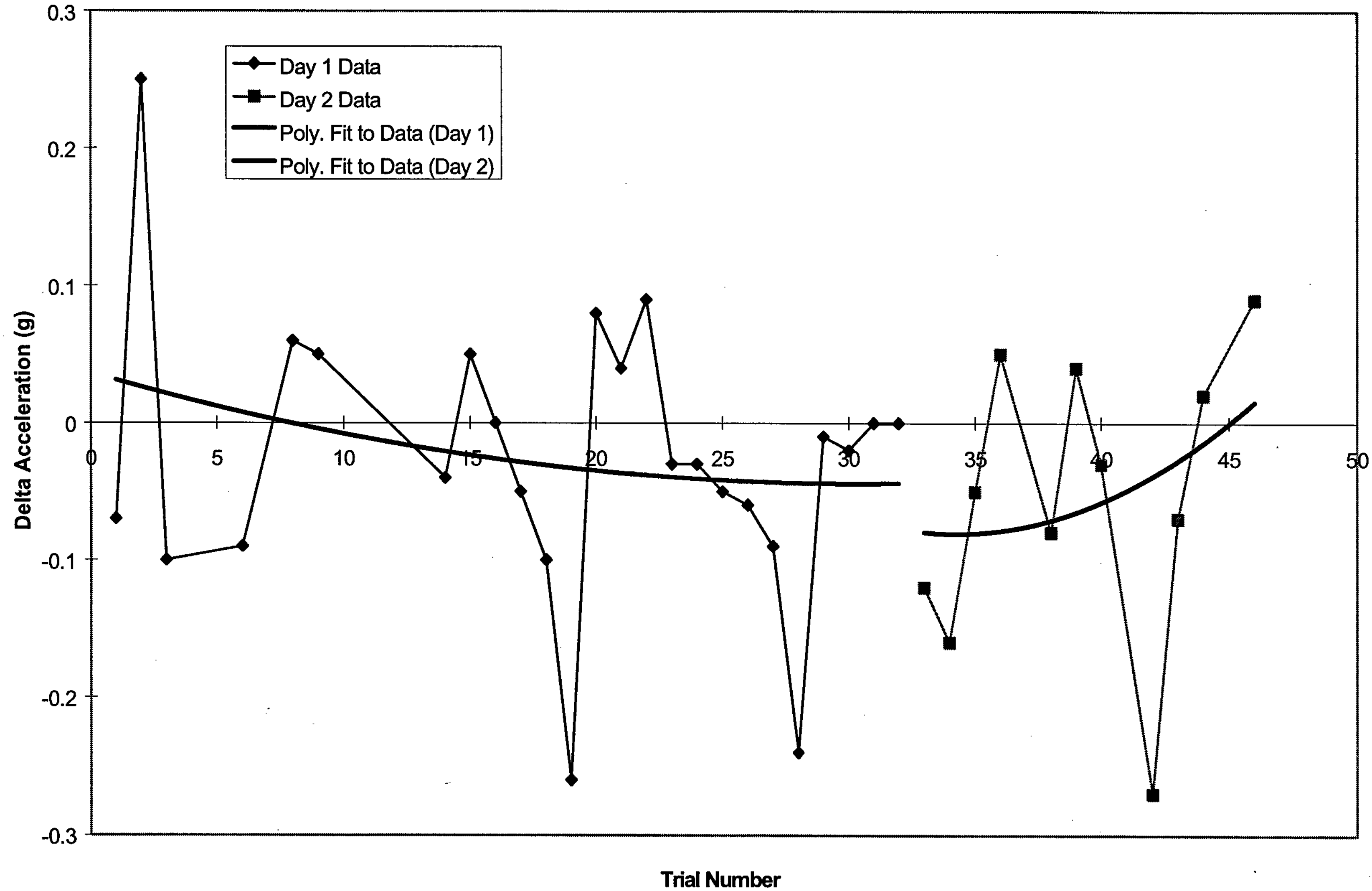


Figure 4.2.3.1-12. Mean Target Acceleration During Missile Flyout Relative to LPN-15 Value (Manual Trials)

Time Required for Manual Runs . The total time required to execute 54 manual V2 replication runs was 4 hours which averaged 13.5 runs/hr (~5 min. between runs). This included the set up time (~1 hour) and the time for five V1 runs in preparation for the V2 runs (10 min.).

Cost of the Manual Runs . The cost of the NAWCWPNS simulation facilities was $6K/hr. Thus, the total cost of the manual runs was $24K.

4.2.3.2 Automatic Replay Runs Results

The manual runs from the first day of the Mission Rehearsal were examined to determine which run best matched the LPN-15 conditions. No single manual run closely matched all conditions simultaneously. Because of this, it was necessary to determine which parameter matches were most critical for the missile flyout. Upon the advice of the AIM-9 expert, the most critical parameters were determined to be lead angle and target aspect angle at launch and the degree to which the target maintains a constant altitude and acceleration during the missile flyout. The run which best matched this combination of criteria was determined to be Manual Trial #15.

Launch Conditions . The launch conditions obtained in each successful V2 run (successful runs were those in which the missile was launched, even if the launch conditions were outside the shot box or the missile flyout was incomplete) were compared to those for Manual Trial #15 and the differences were computed using Equation 4. The resulting differences between the actual launch conditions and the Manual Trial #15 values are given for each automatic replay run in Figures 4.2.3.2-1 through 4.2.3.2-9 (NOTE: the trial numbers in these figures are consecutive for the runs selected and are not the same as the run numbers). These figures also indicate the shot box tolerances for each parameter and show a second degree polynomial fit to the data. The mean and standard deviations for the differences in each launch condition parameter are summarized in Table 4.2.3.2-1. Table 4.2.3.2-1 also compares the automatic replay results to the manual results from Table 4.2.3.1-1.

Table 4.2.3.2-1. Differences Between Actual and Desired Launch Conditions for Automatic Replay and Manual Runs.

Launch Parameter	Auto V2 Runs vs. Manual Trial #15	Manual V2 Runs vs. LPN-15 (Total)
Shooter Velocity	2.40 ± 0.48 ft/s	15.09 ± 12.98 ft/s
Shooter Altitude	-322.9 ± 34.9 ft	26.0 ± 132.1 ft
Target Velocity	0.15 ± 0.18 ft/s	13.50 ± 4.82 ft/s
Target Altitude	-17.1 ± 7.35 ft	69.8 ± 55.5 ft
Difference in Altitudes	-305.9 ± 33.4 ft	-43.8 ± 143.1 ft
Launch Range	58.0 ± 539.6 ft	584.8 ± 435.2 ft
Target Aspect Angle	-2.71 ± 1.98 deg	4.37 ± 2.44 deg
Lead Angle	-1.98 ± 1.22 deg	-2.72 ± 1.41 deg
Flare Initiation Time	0.72 ± 0.54 sec	0.03 ± 1.30 sec

The following conclusions are obtained from the figures and table:

- The automatic replay runs did not perform as hoped. The objective of these w as to achieve exactly the same launch conditions on each run. However, as Table 4.2.3.2-1 shows, this was not the case; there should have been zero biases and spreads.
  - -- The non-zero values for means (biases) and standard deviations (spreads) were due to the manual actions required during the automatic replay runs: manual start of the WSIC and WSSF simulations, manual trigger squeeze by the F/A-18 WSSF pilot, and manual flare initiation. As a result, the start of the simulations was not synchronized to exactly the same conditions each time, and the trigger squeeze did not always occur at the same relative time.
- In comparing the launch conditions from the automatic replay runs to those from the manual runs, the following is noted:
  - -- Shooter velocity, target velocity, and target altitude had small biases and spreads compared to the manual runs. This appears to be due to these parameters remaining relatively constant throughout the Manual Trial #15, so that variations in the time of trigger squeeze did not significantly affect these parameters.
  - -- Target aspect angle and lead angle had about the same biases and spreads compared to the manual runs.
  - -- Shooter altitude and flare initiation time had small spreads compared to the manual runs, but large biases. This appears to be due to using different cues for the manual actions of trigger squeeze and flare initiation, compared to Manual Trial #15. However, use of the new cues in the automatic replay runs was consistent.
  - -- Launch range had a small bias c ompared to the manual runs, but about the same spread. This appears to be due to variations in the time of trigger squeeze.
  - -- Hence, the automatic replay runs did not result in smaller biases and spreads in all launch conditions, compared to the manual runs. In particular, Figures 4.2.3.2-6 through 4.2.3.2-8 show significant run-to-run variations in the following critical launch parameters: launch range, target aspect angle, and lead angle.

The effects of variations in the time of missile launch are illustrated in Figures 4.2.3.2-10 and 4.2.3.2-11. These figures compare the target trajectory during the missile flyout from one of the automatic replay runs with Manual Trial #15. The following is noted:

- These figures show that the replay of the target simulator output from the manual trial overlays the data from the manual trial itself. However, the start and stop of the missile flyout occurred at different times during the automatic replay.
- Figure 4.2.3.2-11 shows a noteworthy feature of the WSIC target simulator: the WSIC output the target altitude in discrete 20 ft increments. Although the WSIC altitude output remained constant until an increment occurred, the PDUs showed small variations in altitude. This occurred because the WSIC NIU dead reckoned the target altitude (from the target's down component of velocity) for the PDU data between the WSIC altitude updates. In other words, the NIU attempted to correct the PDU data for the fact that the target altitude should have actually been changing during each altitude "step." When a

WSIC target altitude update was received at the NIU, the PDU data were "corrected" back to the discrete values output by the WSIC.

- When the WSIC output was replayed, new target entity state PDUs were created. As Figure 4.2.3.2-11 shows, the altitude variations in the replayed PDUs did not exactly overlay the original PDU data.
- The variations in the start of the replayed manual data resulted in variations in the engagement conditions.

As Figures 4.2.3.2-10 and 4.2.3.2-11 show, the replayed data tracked the manual run, except for the small altitude variations. However, the manual actions required for the automatic replay runs resulted in the target being at slightly different locations at missile launch, relative to the manual trial. These offsets in the target location at launch are illustrated in Figure 4.2.3.2-12. The mean and standard deviation of the offsets were -32.6 $\pm$ 379.6 ft. Hence, there was a small bias, but a large spread in the offset of the target location at launch for the automatic replay runs relative to the manual run.

Another problem was found with the replayed target PDU data. The target PDUs from the replay runs had repeating PDUs, whereas the manual data did not. In other words, during the replay, several identical PDUs in a row were logged. These repeating PDUs all had the same PDU time and the same entity state data. As many as 12 in a row were observed on some runs. Since the SIMLAB missile simulation integrated the target velocity to determine the target location, these repeating PDUs aggravated the target latitude divergence problem (Section 4.1.1.3). In other words, the SIMLAB target representation during the automatic replay runs was north of that from the manual run being replayed. That this is the case is best illustrated by comparing the times-of-flight. The TOF of every automatic replay run was longer than the TOF of the manual run, even though a number of the replay runs had shorter launch ranges (Fig. 4.2.3.2-6). The mean and standard deviation of the TOFs for the automatic replay runs was 0.33 $\pm$ 0.20 seconds longer than the TOF of the manual run.

Hence, the automatic replay runs did not achieve their purpose: perfect replication of the launch conditions and perfect replication of the target trajectory each time. For this reason, the automatic replay runs were not executed on subsequent missions.

Time Required for Automatic Replay Runs. The total time required to execute 34 automatic V2 runs was 4 hours which averaged 8.5 runs/hr (~7 min. between runs). This included the set up time (~1 hour) and the time for five V1 runs in preparation for the V2 runs (10 min.).

Cost of the Automatic Replay Runs. The cost of the NAWCWPNS simulation facilities was $6K/hr. Thus, the total cost of the automatic replay runs was $24K.

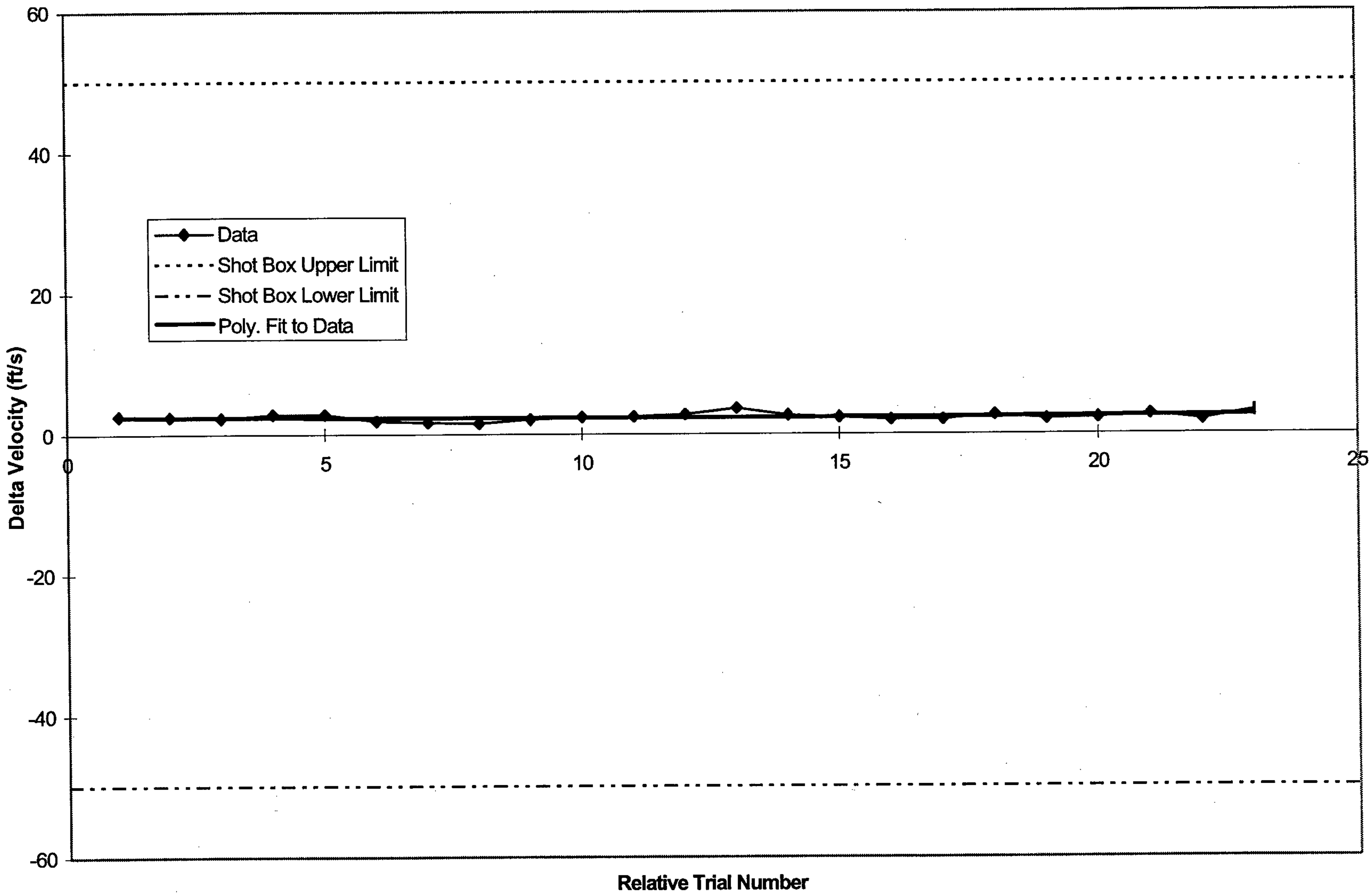


Figure 4.2.3.2-1. Shooter Velocity Relative to Manual Trial #15 Value (Automatic Replay Trials)

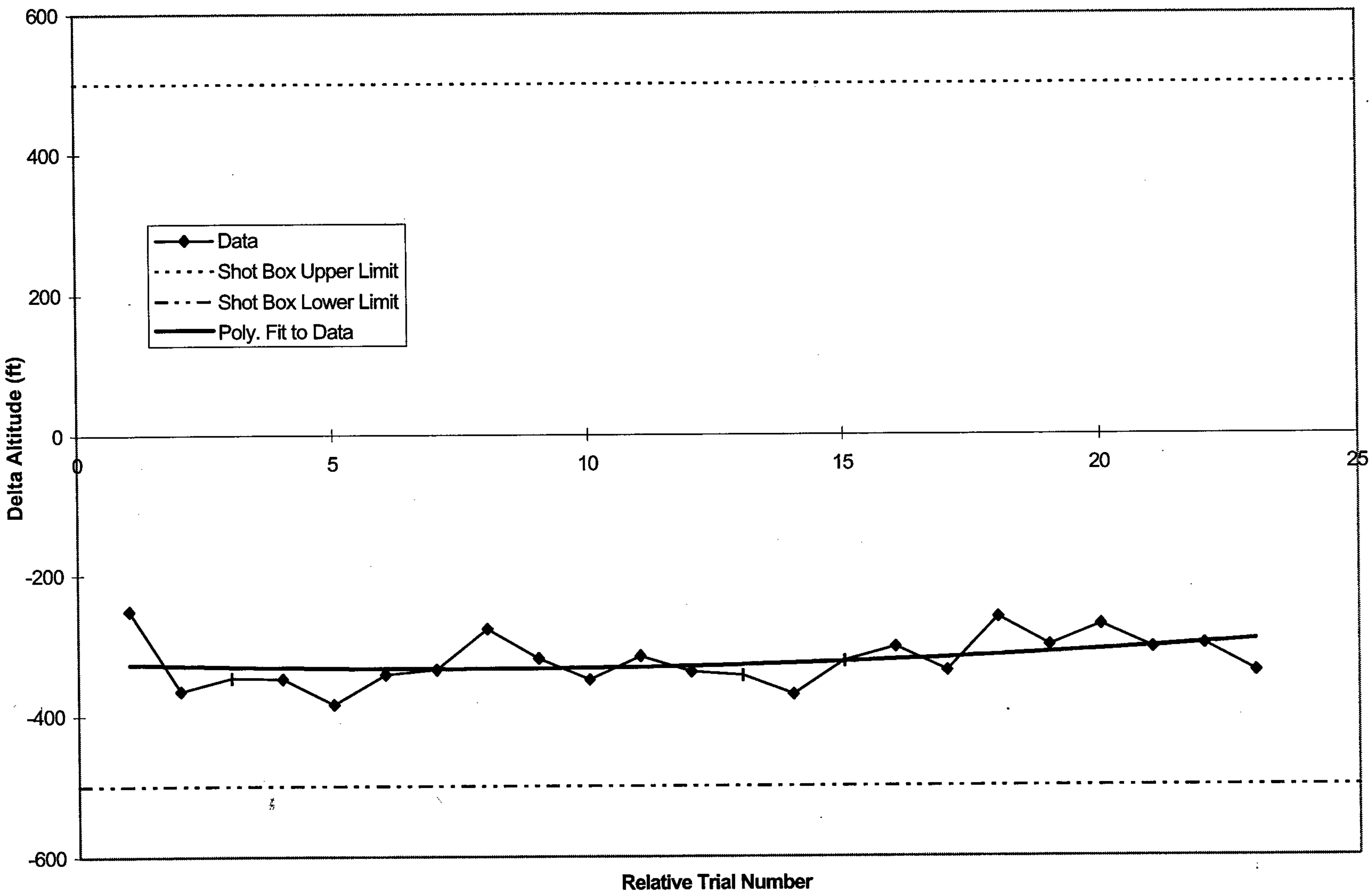


Figure 4.2.3.2-2. Shooter Altitude Relative to Manual Trial #15 Value (Automatic Replay Trials)

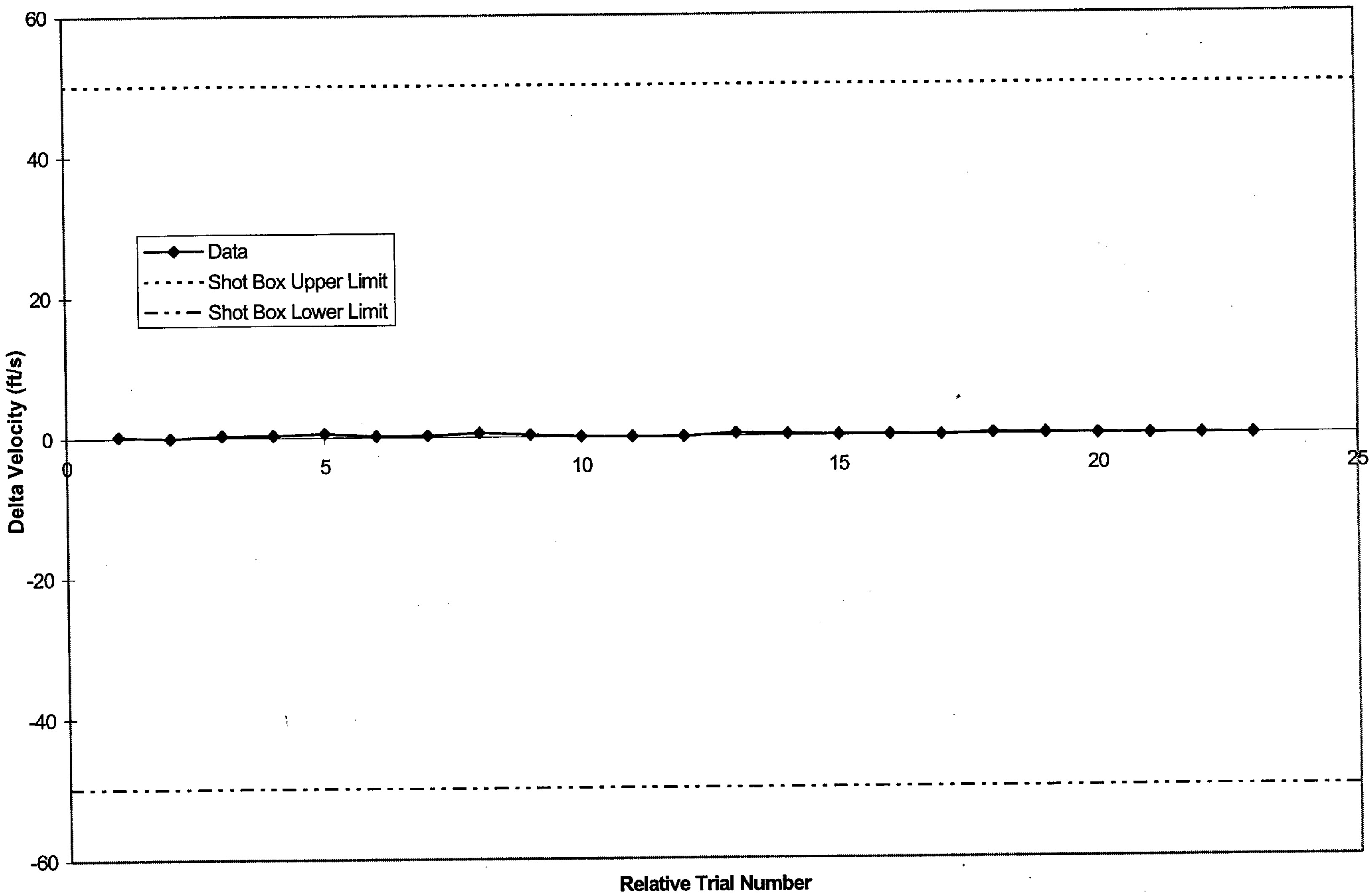


Figure 4.2.3.2-3. Target Velocity Relative to Manual Trial #15 Value (Automatic Replay Trials)

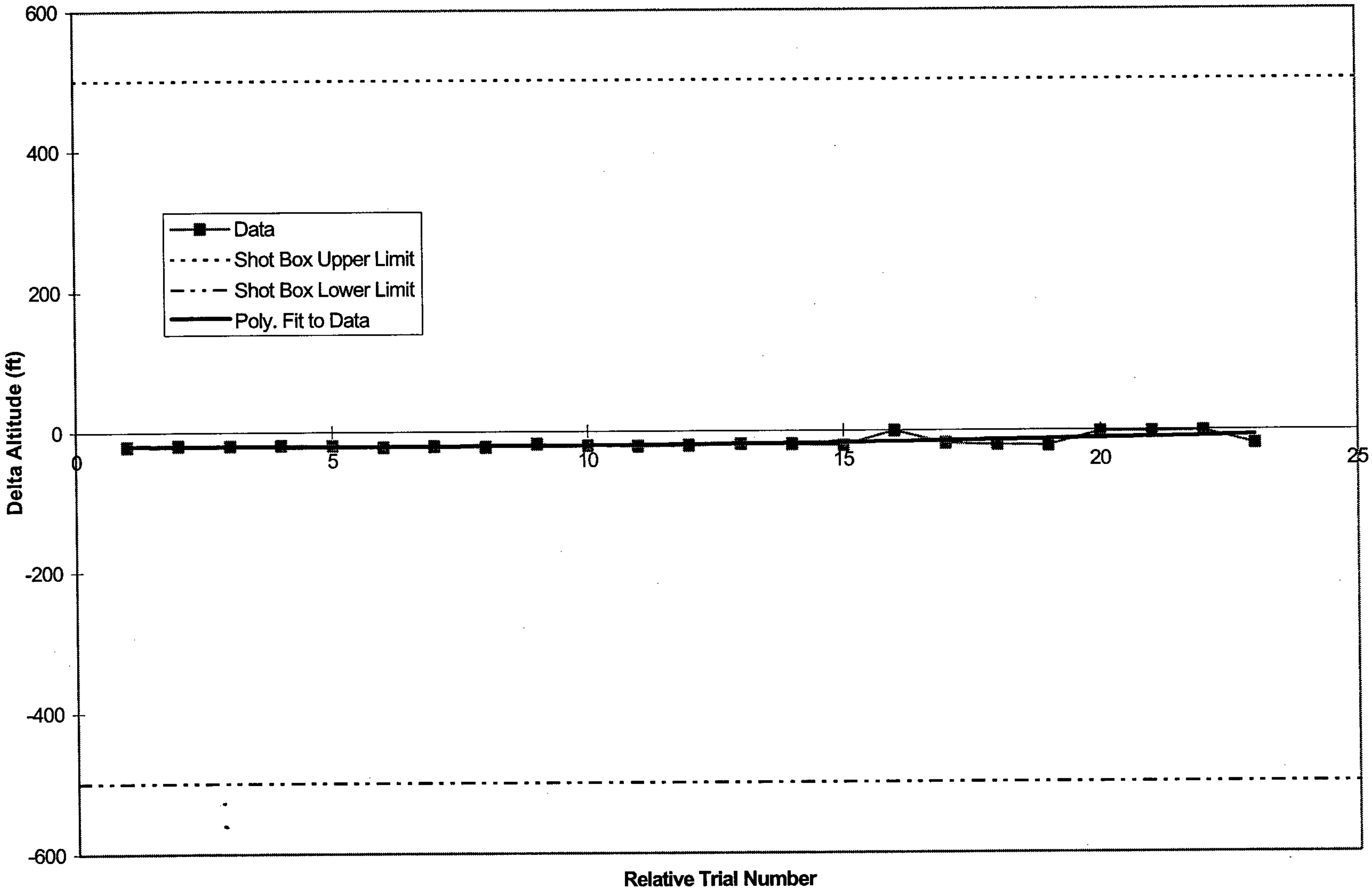


Figure 4.2.3.2-4. Target Altitude Relative to Manual Trial #15 Value (Automatic Replay Trials)

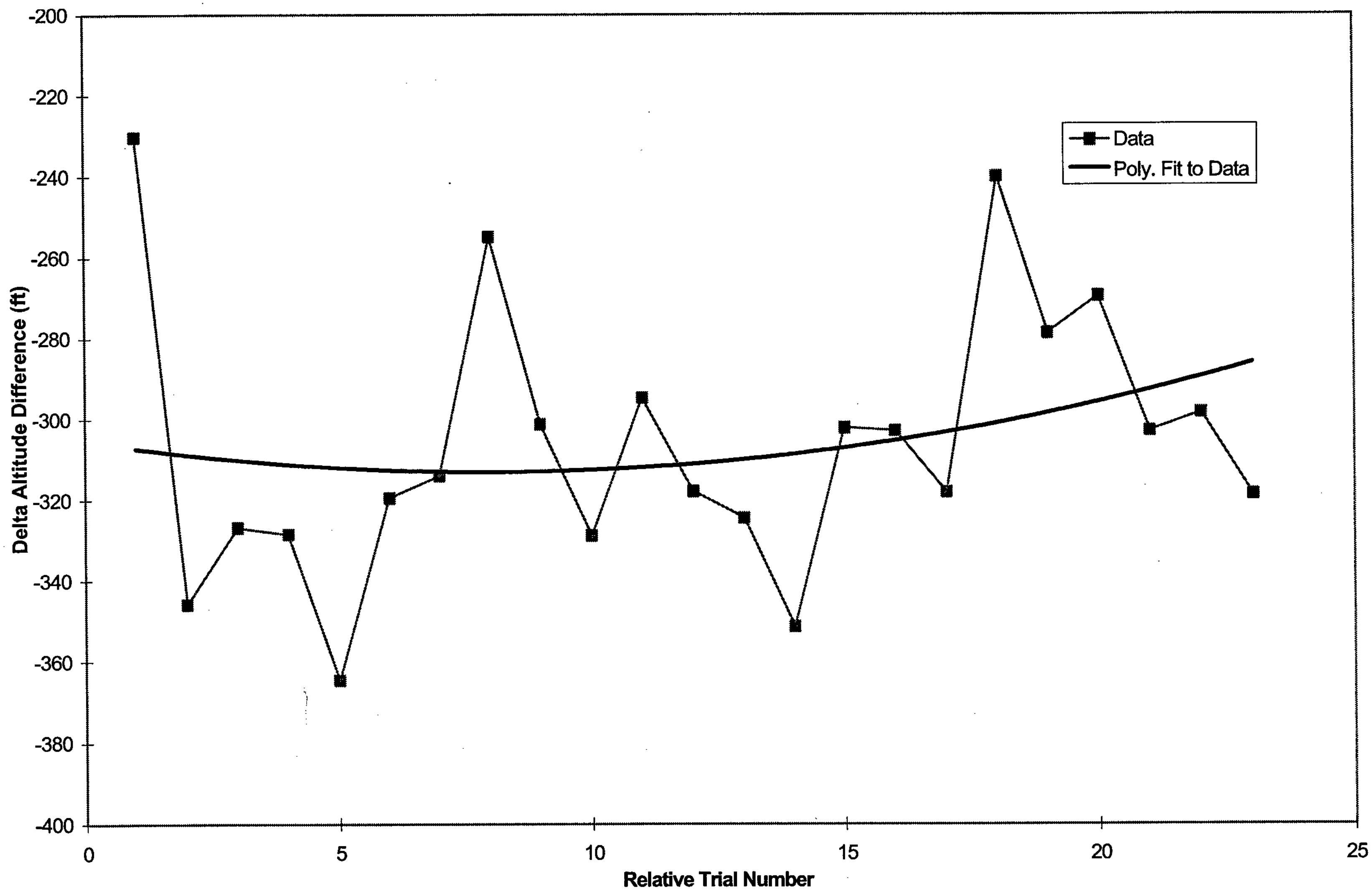


Figure 4.2.3.2-5. Shooter and Target Altitude Difference Relative to Manual Trial #15 Value (Automatic Replay Trials)

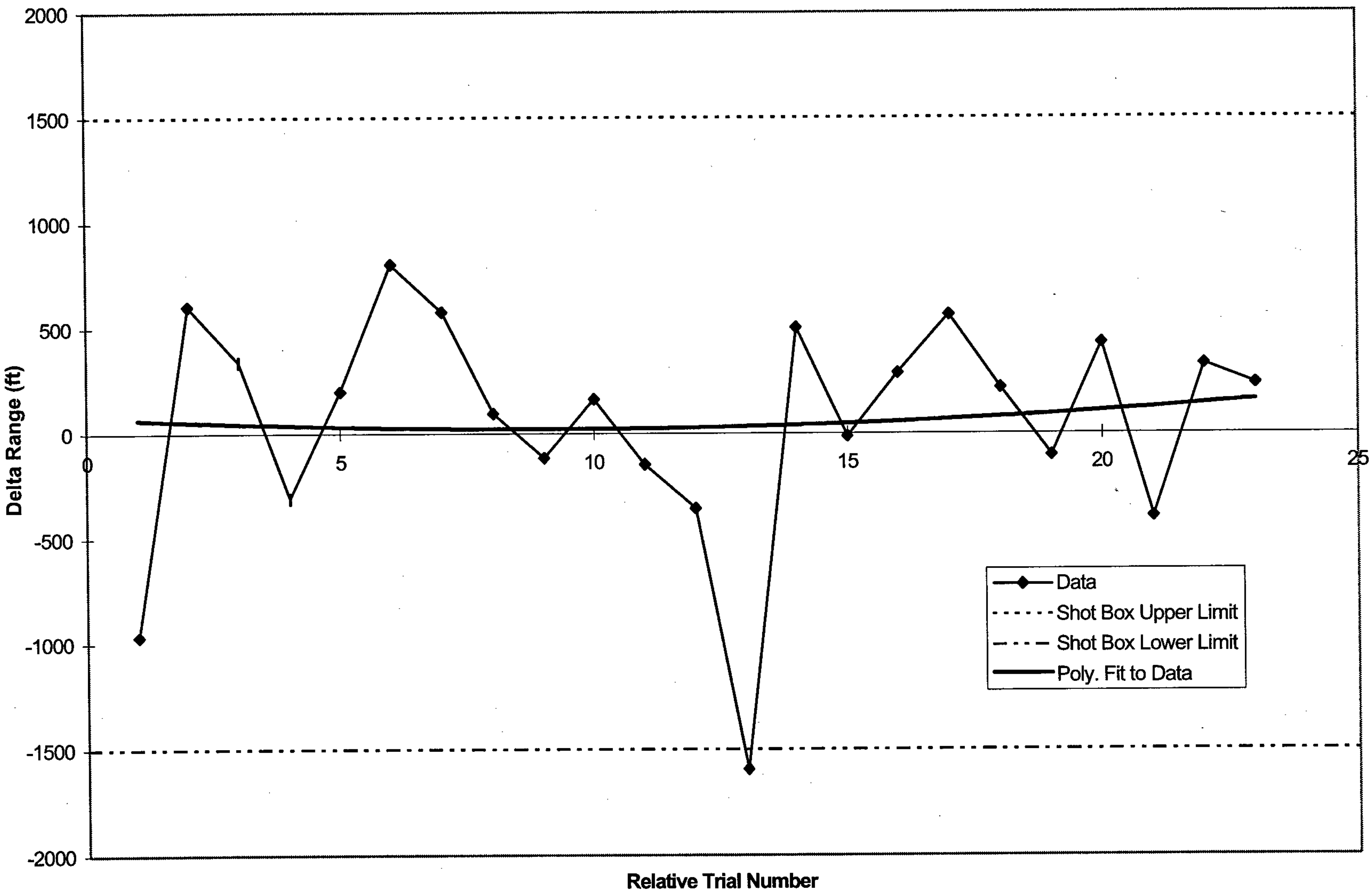


Figure 4.2.3.2-6. Launch Range Relative to Manual Trial #15 Value (Automatic Replay Trials)

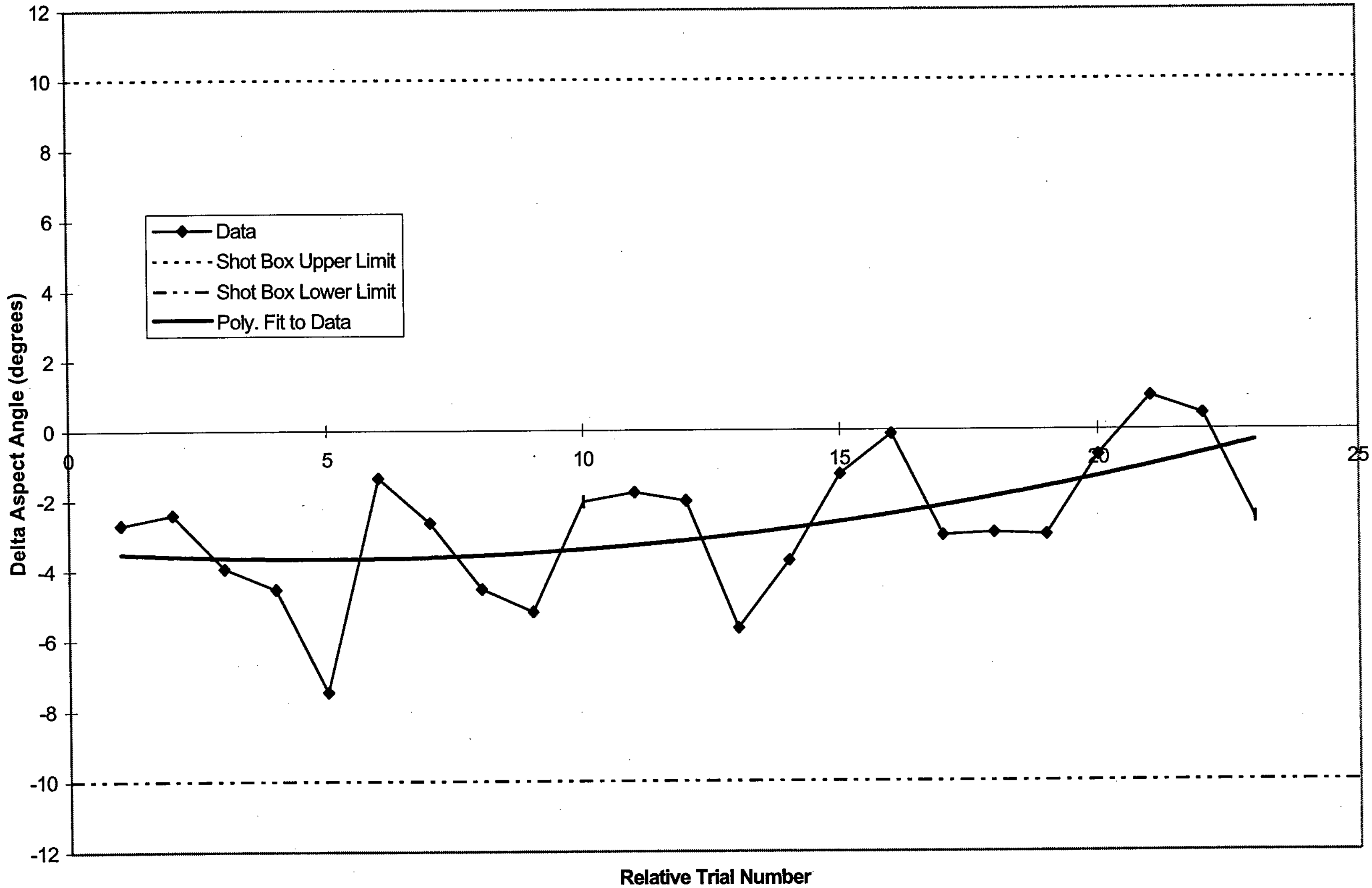


Figure 4.2.3.2-7. Target Aspect Angle Relative to Manual Trial #15 Value (Automatic Replay Trials)

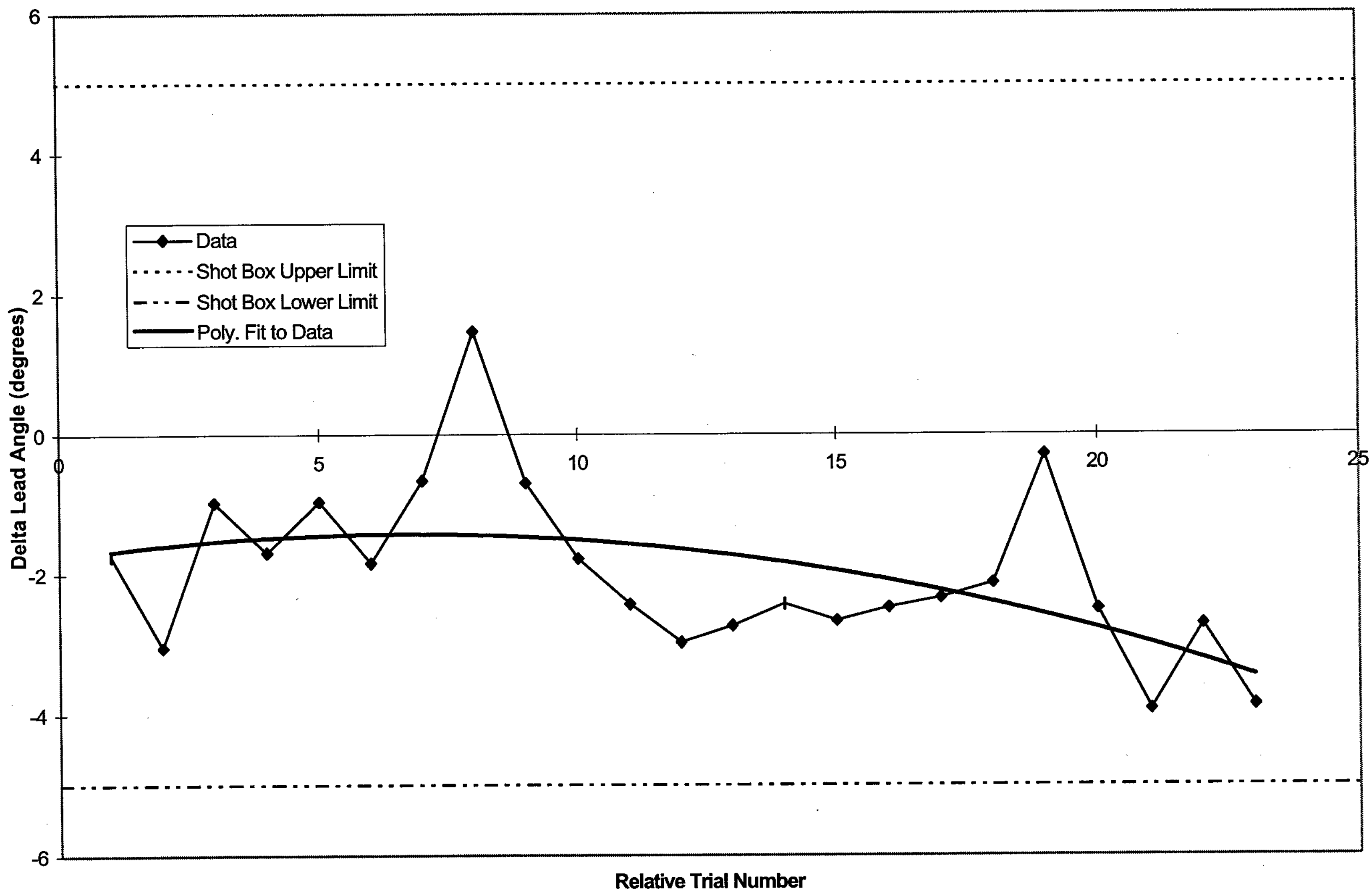


Figure 4.2.3.2-8. Lead Angle Relative to Manual Trial #15 Value (Automatic Replay Trials)

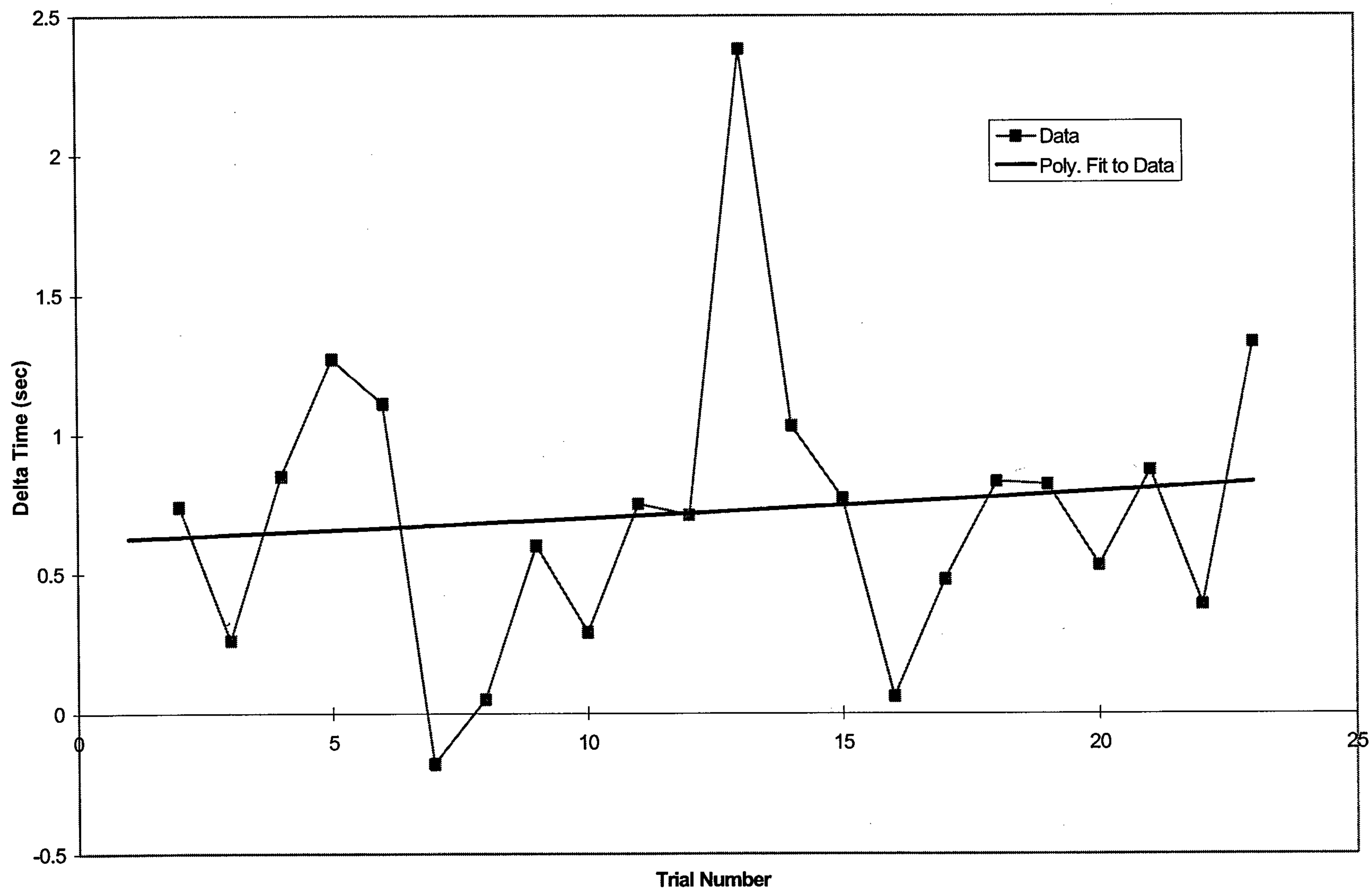


Figure 4.2.3.2-9. Flare Initiation Time Relative to Manual Trial #15 Value (Automatic Replay Trials)

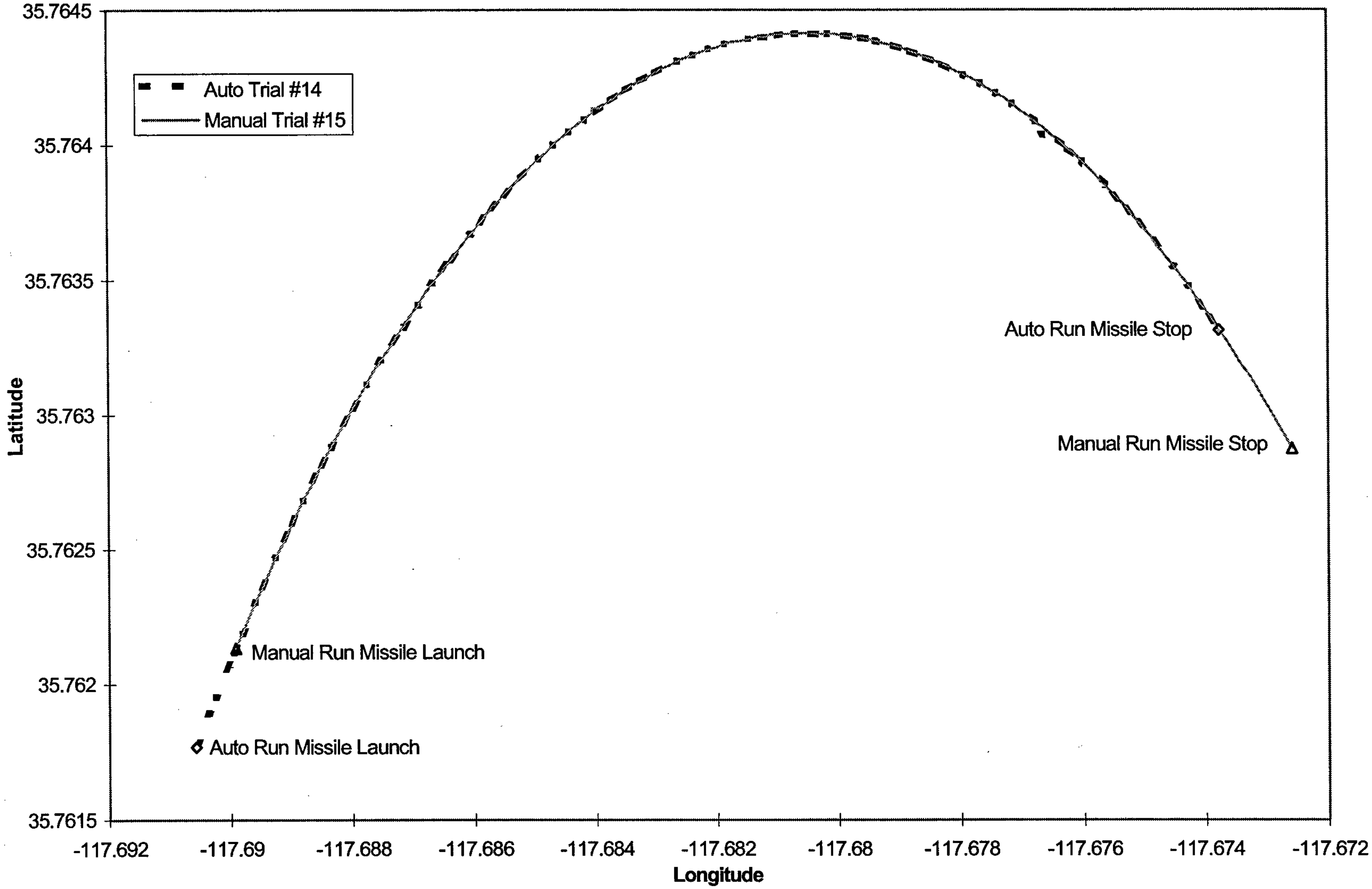


Figure 4.2.3.2-10. Comparison of Target Trajectory From Automatic Replay Trial #14 with Manual Trial #15

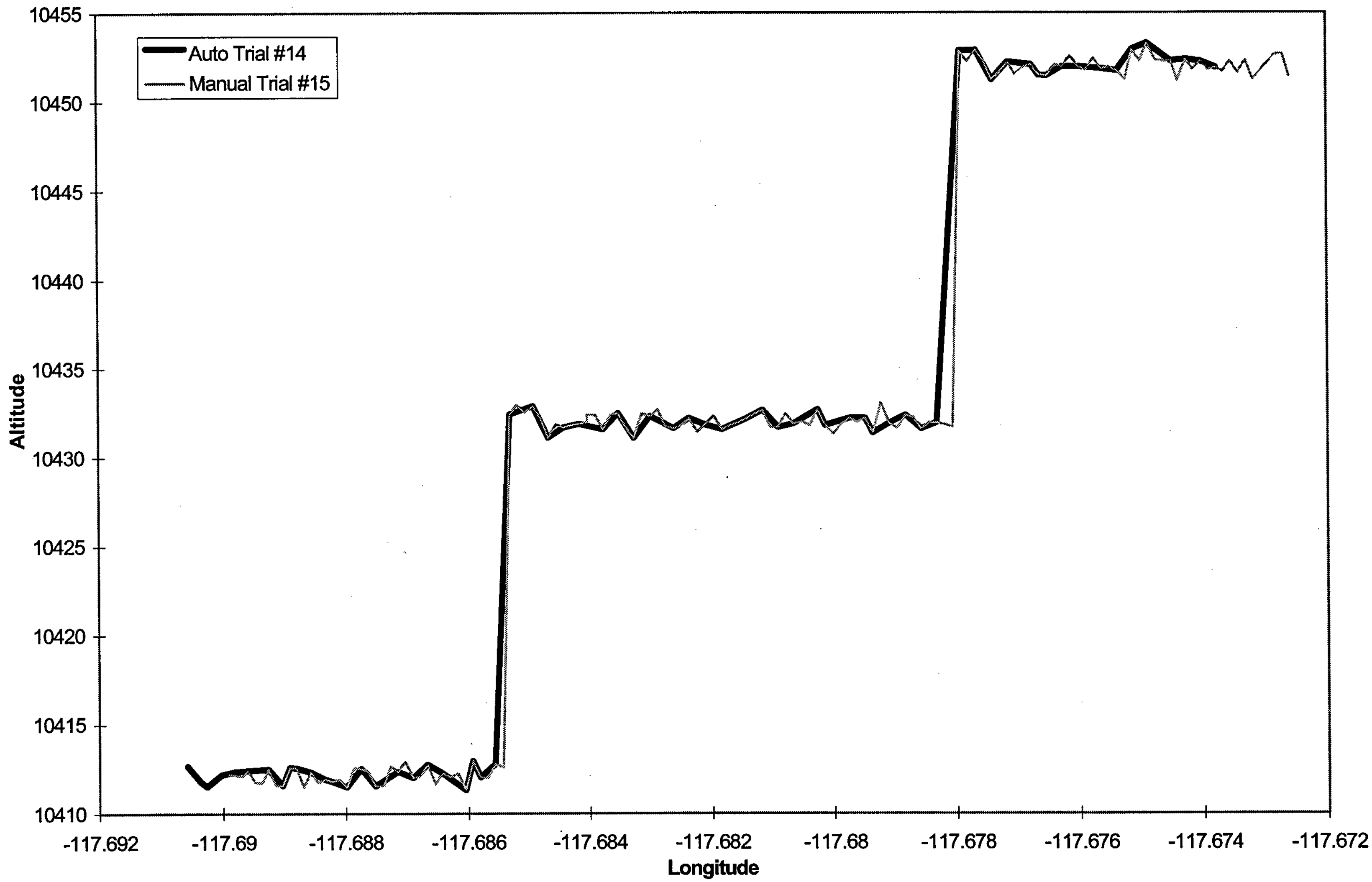


Figure 4.2.3.2-11. Comparison of Target Trajectory From Automatic Replay Trial #14 with Manual Trial #15

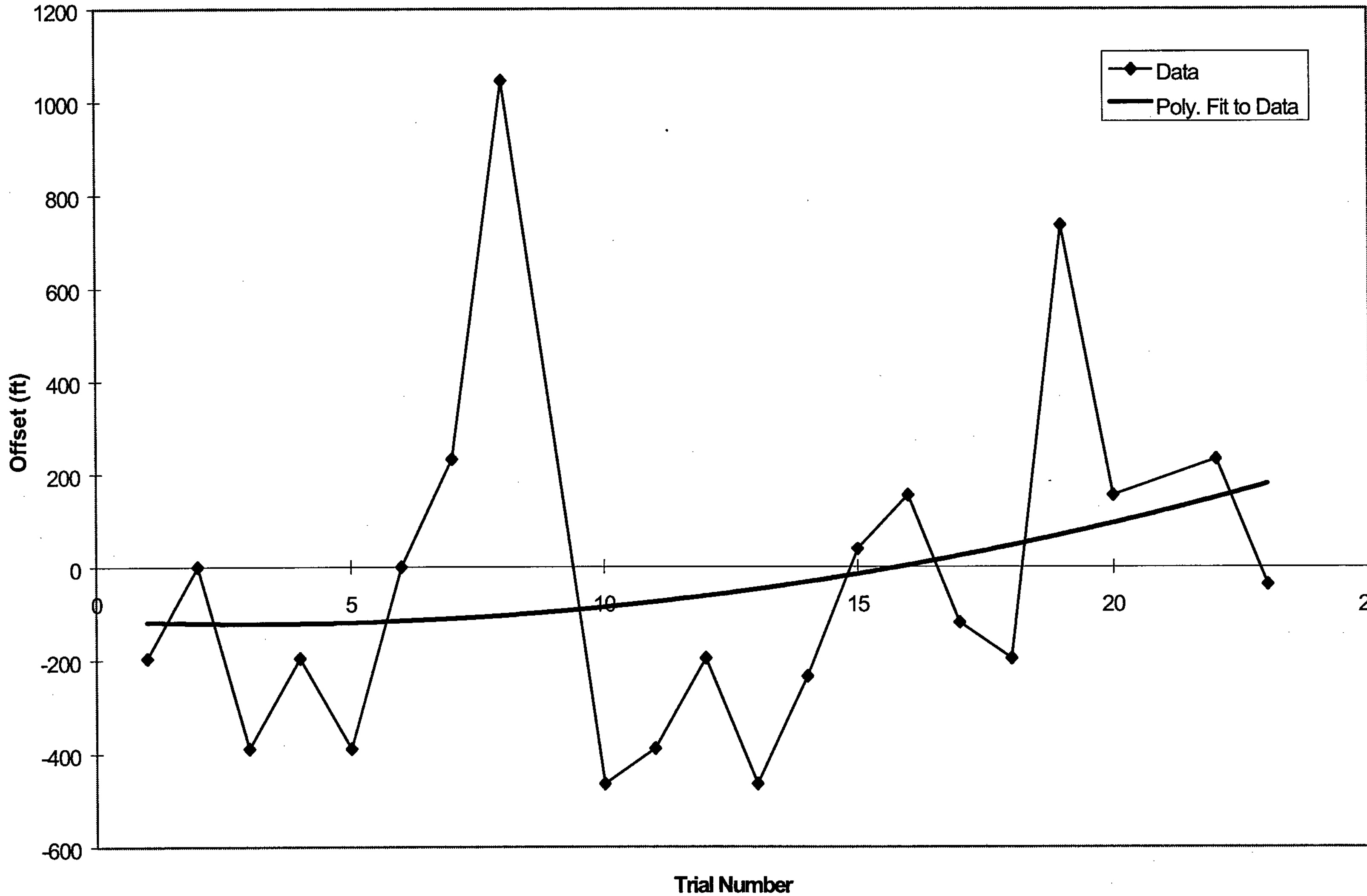


Figure 4.2.3.2-12. Offset in Target Position at Missile Launch Relative to Manual Trial #15 Value (Automatic Replay Trials)

4.2.4 Parametric Study Summary

The manual method for replicating a given profile resulted in very good run-to-run reproducibility of the launch conditions. However, the automatic replay method was unable to precisely replicate a given scenario. Hence, the manual method can effectively support parametric studies, but the automatic replay method, as implemented in the Mission Rehearsal, cannot.

In order for the automatic replay method to be effective, the manual actions required in the LSP trials need to be replaced with automatic procedures. This would have required significant modifications of the NAWCWPNS simulators and was beyond the scope of the LSP. However, future implementations of this concept may be able to overcome this limitation.

4.3 Test Objective 3: Assess effect of latency on validity of test results

This objective is to evaluate the effects of latency on test results. An issue here is that when there is significant latency, the different simulation nodes experience a "different" engagement. Although the missile simulation may continue to successfully intercept the target in the engagement presented to it at the SIMLAB node, this will not be exactly the same engagement as that experienced by either the target or the shooter. In other words, with "too much" latency, the planned engagement cannot be executed. Further, "too much" latency will invalidate the results of a reactive scenario (missile and target are reacting to each other).

4.3.1 Latency Study Test Method

The Latency Study Mission was designed to accomplish this test objective and was to utilize a reactive scenario in which the target reacted to the missile from cues generated by the missile warning system model. Note that this would not be the V&V scenario, LPN-15 (which did not involve the missile warning system model). Rather, a scenario was to be selected from the planned Parametric Mission in which the warning system/CM clearly affected the missile performance.

One flight profile was planned for the Latency Study Mission: the reactive profile selected from the Parametric Study Mission. The latency study was to be performed by first replicating this profile for the baseline minimum latency case (inherent system/network latency only) and noting the engagement results for each node. Next the profile was to be repeated with an adjustable time delay at the WSIC node only and again the engagement results for each node were to be noted. The delay was to be between the network and the WSIC NIU and was to affect both incoming and outgoing PDUs. The profile was to be repeated with additional increments of time delay at the WSIC node.

Features of this mission were to be as follows.

- The time delays were to be introduced only at the WSIC node. The link between the WSSF and the SIMLAB was not to be affected. The reason for not adding time delays between the WSSF and SIMLAB was that there were two links between these facilities

(one for PDU data and one for SMS data), delays would have to be added to both links simultaneously, and significant delays could not be added to the SMS link without affecting the proper operation of the SMS system. Adding delays only at the WSIC node would have simulated the situation of moving the target node to a geographically remote location, while keeping the shooter and missileco-located.

- The values of time delay was to be set in a computer in the WSIC which was located between the Cisco router and the rest of the WSIC network. This was the first processing point in the WSIC encountered by incoming PDUs and the last processing point encountered by outgoing PDUs. The computer was to buffer the PDUs until the preset delay time had elapsed. At that time, the computer was to transmit the PDUs. The actual simulation-computer-to-simulation-computer latency was to be measured before each run by generating a fire flare signal in the WSIC (with generation time stamp) and recording its input into another simulation computer (with input time stamp). Latency between the WSIC and the BMIC/TCAC was to determined from the time stamp when the Fire (Flare) PDU was recorded in the PDU logger located in the BMIC/TCAC.

- Initial increments of time delay to be implemented were to be determined after analysis of the V&V and Parametric Mission results. The increments were to be adjusted after quick-look analysis of the initial results, in order to better identify the onset of significant latency effects.

As the time delay was increased, the engagement viewed at each of the four nodes (WSSF, SIMLAB, WSIC, TCAC) was expected to increasing differ in terms of launch range, flare release/target maneuver time, and miss distance.

4.3.2 Latency Study Analysis Method

Runs of the selected profile were to be evaluated to determine the range of acceptable initial launch conditions and target trajectories/profiles. The evaluation criterion was to be that these ranges of conditions/parameters for the shooter and target result in acceptable ranges of variations in the missile trajectory/profiles (based on the judgment of AIM-9 expert). The result was to be acceptable ranges for the following:

- Shooter initial conditions, as measured in the WSSF
- Launch range, as measured in the WSSF
- Target initial conditions, as measured in the WSIC
- Flare dispense time relative to missile warning cue, as measured in the WSIC
- Target evasive maneuver time and profile upon missile warning cue, as measured in the WSIC
- The terms "as measured in the WSSF" or "as measured in the WSIC" mean that these parameters were evaluated from data recorded and time stamped on the simulation computer of the corresponding facility.

These acceptable ranges were to form screening criteria for subsequent runs involving additional time delays. Runs meeting the criteria were to be analyzed for latency effects, and runs not meeting the criteria were not to be further analyzed.

The runs meeting the screening criteria were to be independently analyzed at each facility (WSSF, SIMLAB, WSIC, and TCAC) for each time delay increment. Using data recorded at each facility, the following were to be determined:

- Launch Range. This was computed from the difference in the positions of the shooter and the target when either the missile launch event indicator was recorded in the simulation computer (for simulation facilities) or when the Fire (Missile) PDU was recorded in the TCAC PDU logger. The indicators used for missile launch differed for the various simulations and will be discussed with the analysis results.

- Target Aspect at Launch. This was computed from the difference in the attitudes of the shooter and the target when either the missile fire event indicator was recorded in the simulation computer (for simulation facilities) or when the Fire (Missile) PDU was recorded in the TCAC PDU logger. The aspect angle was computed as follows:
  - -- The shooter and target locations were projected onto the local tangent plane (i.e., the local horizontal plane or the "God's-eye" view).
  - -- The direction of th e line-of-sight (LOS) vector from the shooter to the target in the local tangent plane, Σ_{RA}, (see Fig. 4.3.2-1) was computed using:

$$\Sigma_{RA} = \tan^{-1}\left[\frac{\Delta\text{lon}\ \cos(\text{lat}_t)}{\Delta\text{lat}}\right] \tag{5}$$

where Δlon = longitude of target - longitude of shooter
Δlat = latitude of target - latitude of shooter
lat_t = latitude of target

  - -- The target aspect angle, σ_A, was computed using (see Fig. 4.3.2-1):

$$\sigma_A = b_T - \Sigma_{RA} \tag{6}$$

where b_T = bearing of target (the direction of the target's velocity vector, $\mathbf{v}_T$, projected onto the local tangent plane) measured from north

  - -- Initially, the target aspect angle was computed using the target heading in place of the bearing. However, it was determined that the shooter's radar uses the target bearing in live shots. In order to compare to LPN-15 test data and to the aspect angle from the WSSF F/A-18 simulator, the calculation for aspect angle was revised to use target bearing (Eqn. 6). Note that the target's heading (direction nose is pointed, as projected on the tangent plane) does not coincide with the target bearing when the target is turning, due to the aircraft angle of attack.

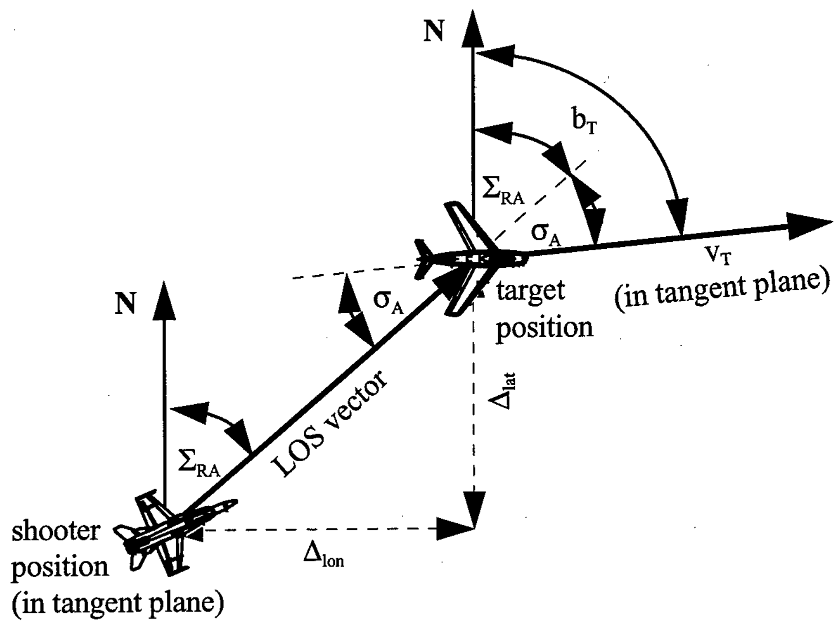


Figure 4.3.2-1. Geometry for Calculating Target Aspect Angle, σ_A (positions and v_T projected into horizontal tangent plane)

- Lead Angle. This was computed from the difference in the heading of the shooter and the direction of the LOS vector when either the missile fire event indicator was recorded in the simulation computer (for simulation facilities) or when the Fire (Missile) PDU was recorded in the TCAC PDU logger. The lead angle was computed as follows:
  - -- The shooter and target locations were projected onto the local tangent plane (i.e., the local horizontal plane or the "God's-eye" view).
  - -- The direction of the LOS vector from the shooter to the target in the local tangent plane, Σ_{RA}, (see Fig. 4.3.2-1) was computed using Equation 5.
  - -- The lead angle, ψ, was computed using (see Fig. 4.3.2-2):

$$\psi = h_S - \Sigma_{RA} \tag{6}$$

where h_S = heading of shooter (the direction of the sh ooter's nose, projected onto the local tangent plane) measured from north

- Shooter Altitude. This was determined by the shooter altitude when either the missile fire event indicator was recorded in the simulation computer (for simulation facilities) or when the Fire (Missile) PDU was recorded in the TCAC PDU logger.
- Time of Launch. This was determined by the time at which either the missile fire event indicator was recorded in the simulation computer (for simulation facilities) or when the Fire (Missile) PDU was recorded in the TCAC PDU logger.

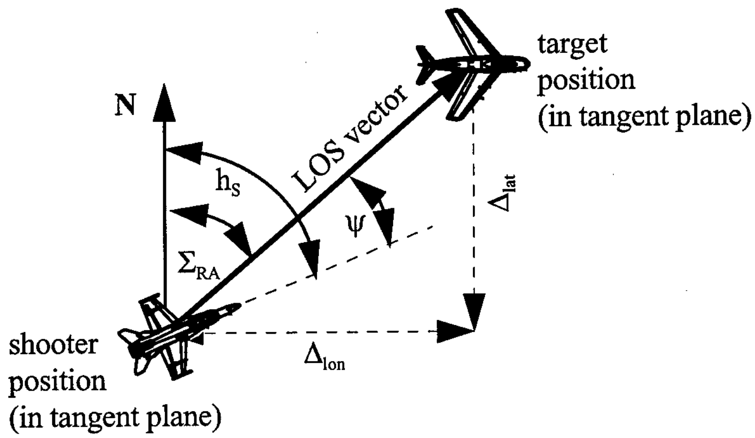


Figure 4.3.2-2. Geometry for Calculating Lead Angle, ψ (positions projected into horizontal tangent plane)

- Time of Flare Release. This was to determined by the time at which either the flare fire event indicator was recorded in the simulation computer (for simulation facilities) or when the Fire (Flare) PDU was recorded in the TCAC PDU logger.
- Time of Evasive Maneuver. This was to be determined by the time at which the target acceleration began to increase from the baseline value (3.5 g) to the evasive maneuver value (7+ g).
- Time of Missile Detonation. This was to be determined by the time at which either the missile detonation event indicator was recorded in the simulation computer (for simulation facilities) or when the Detonation PDU was recorded in the TCAC PDU logger.
- Miss Distance. This was to be computed from the difference in the positions of the missile and the target when either the missile detonation event indicator was recorded in the simulation computer (for simulation facilities) or when the Detonation PDU was recorded in the TCAC PDU logger.

The average values for each of the above parameters, as determined at each facility, were to be computed for each profile (i.e., for each value of time delay).

The average parameter values for the SIMLAB stand-alone profile (L1-S) were to be taken as the baseline values.

For each profile (each time delay), the difference between the average value of each parameter (as determined at each of the four facilities) and the baseline value was to be computed.

The actual simulation-computer-to-simulation-computer latency was to have been measured for each profile (time delay setting) as follows:

- A fire flare signal was to be manually generated in the WSIC. This signal was to be recorded in the WSIC simulation computer, along with the associated time stamp for time of generation.

- When the fire flare signal was received at the other simulation computers, it was to be recorded there, along with a time stamp for the time of input into the receiving computer.
- When the Fire (Flare) PDU created at the WSIC was received at the BMIC/TCAC, it was to be recorded on the PDU logger located there, along with a time stamp for the time of receipt.
- The latency between each receiving simulation computer or the BMIC/TCAC and the WSIC simulation computer was to be computed as the difference between the time of receipt and the time of generation at the WSIC.
- This procedure was to be repeated a number of times bef ore the actual trials of the profile began. Latency results were to be analyzed to determine the following latency statistics: relative frequency histogram, mean, median, mode, and variance.

4.3.3 Latency Study Results

The Latency Study Mission was not executed. Schedule slips caused by problems with V&V of the LSP architecture resulted in the Parametric Study Mission being executed during the time frame originally planned for the Latency Study Mission. In addition, an abundance of latency data was collected in the other missions, and the Latency Studies Mission was judged to be redundant. Hence, a mission was not performed in which latency was treated as a controlled variable. Instead, latency data from the other missions were used to analyze this test objective.

4.3.3.1 Latency Characteristics

First, the characteristics of latency were determined. The method for computing latency discussed above was to use the Fire (Flare) PDU created at the WSIC and assumed a constant latency value between the WSIC and the other nodes. However, no runs were completed in which a Fire (Flare) PDU was created at the WSIC. Further, the latency values between each pair of nodes were found to vary significantly during a run.

Instead, latency values were calculated throughout a run from the differences in time stamps for the same set of entity state data logged at various locations. Latency was computed for each set of entity state data transmitted between two logging locations during a run, as follows:

- When latency was to be determined between a creating simulation and a PDU logger, the values of the entity state data were used to match a simulation frame with a PDU, and the latency was computed from the difference between the PDU log time (when the PDU was logged) and the PDU time (when the data originated in the creating simulation).
- When latency was to be determined between PDU loggers, the PDU time was used to match the PDUs, and the latency was computed from the difference between the log times.
- When latency was to be determined between a PDU logger and a receiving simulation, the values of the entity state data were used to match a PDU with a simulation frame, and the latency was computed from the difference between the time stamp of the simulation frame and the PDU log time.

- When latency was to be determined between simulations, the values of the entity state data were used to match simulation frames, and the latency was computed from the difference between the time stamps of the matching simulation frames.

The latency between various pairs of logging locations was characterized by its time variation, frequency distribution, mean value, standard deviation, minimum value, and maximum value.

Mission Rehearsal Latencies

Latencies could not be determined from the first day of testing (8/27/96) due to a problem with the logging time stamp. The time stamp on the STRICOM PDU loggers was off from the IRIG time used by the NAWCWPNS simulators by about 15 sec. This problem was fixed for the second day (8/28/96) of the Mission Rehearsal. Tables 4.3.3.1-1 and 4.3.3.1-2 present samplings of latency data from the second day, and Figures 4.3.3.1-1 through 4.3.3.1-5 show latency as a function of PDU time (the PDU time uniquely identifies an entity state PDU) for several entity/run combinations.

Table 4.3.3.1-1. Latencies (in msec) of Target Entity State Data (8/28/96)

Run #	WSIC Sim to WSIC Logger				WSIC Sim to SIMLAB Logger				Btwn Loggers
	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean
1	276.5	140.2	26	528	316.3	126.2	80	554	39.8
10	275.5	139.8	40	512	314.9	126.1	87	543	39.4
48	271.1	140.3	32	576	311.3	126.2	92	599	40.2
51	266.9	140.1	33	551	306.1	126.1	92	577	39.2

Table 4.3.3.1-2. Latencies (in msec) of Shooter and Missile Entity State Data (8/28/96)

	Shooter Entity State Data (before launch) WSSF Sim to SIMLAB Logger				Missile Entity State Data SIMLAB Sim to SIMLAB Logger			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
6	24.6	11.3	6	63	677.4	129.2	404	1025
8	37.0	26.8	13	166	548.4	112.0	371	680
46	34.7	23.8	6	137	593.4	98.6	535	915
51	67.7	120.4	6	977	51.1	24.5	-10	148

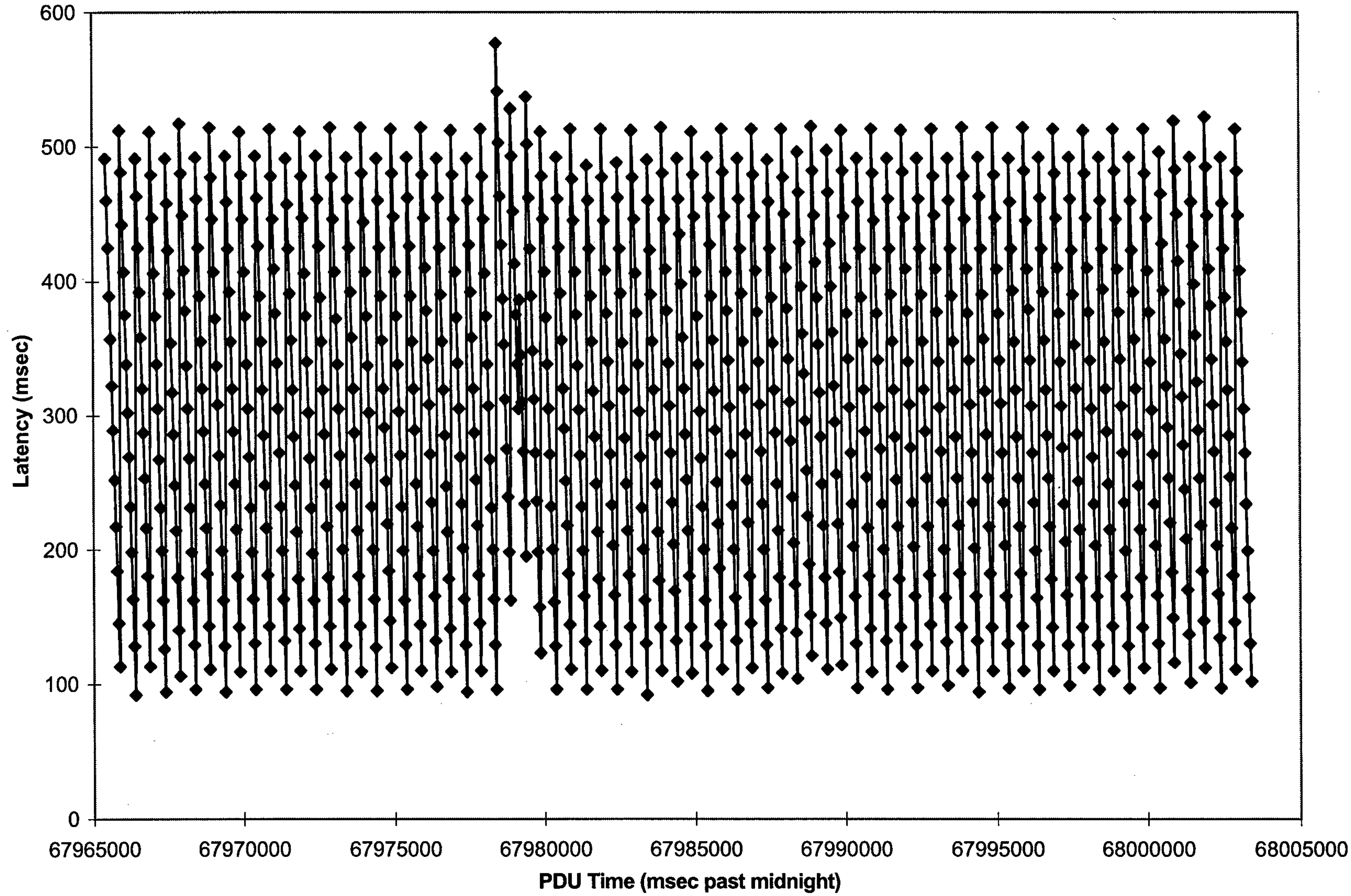


Figure 4.3.3.1-1. Latency of Target Entity State Data Between WSIC Simulation and SIMLAB PDU Logger (Run #51 on 8/28/96)

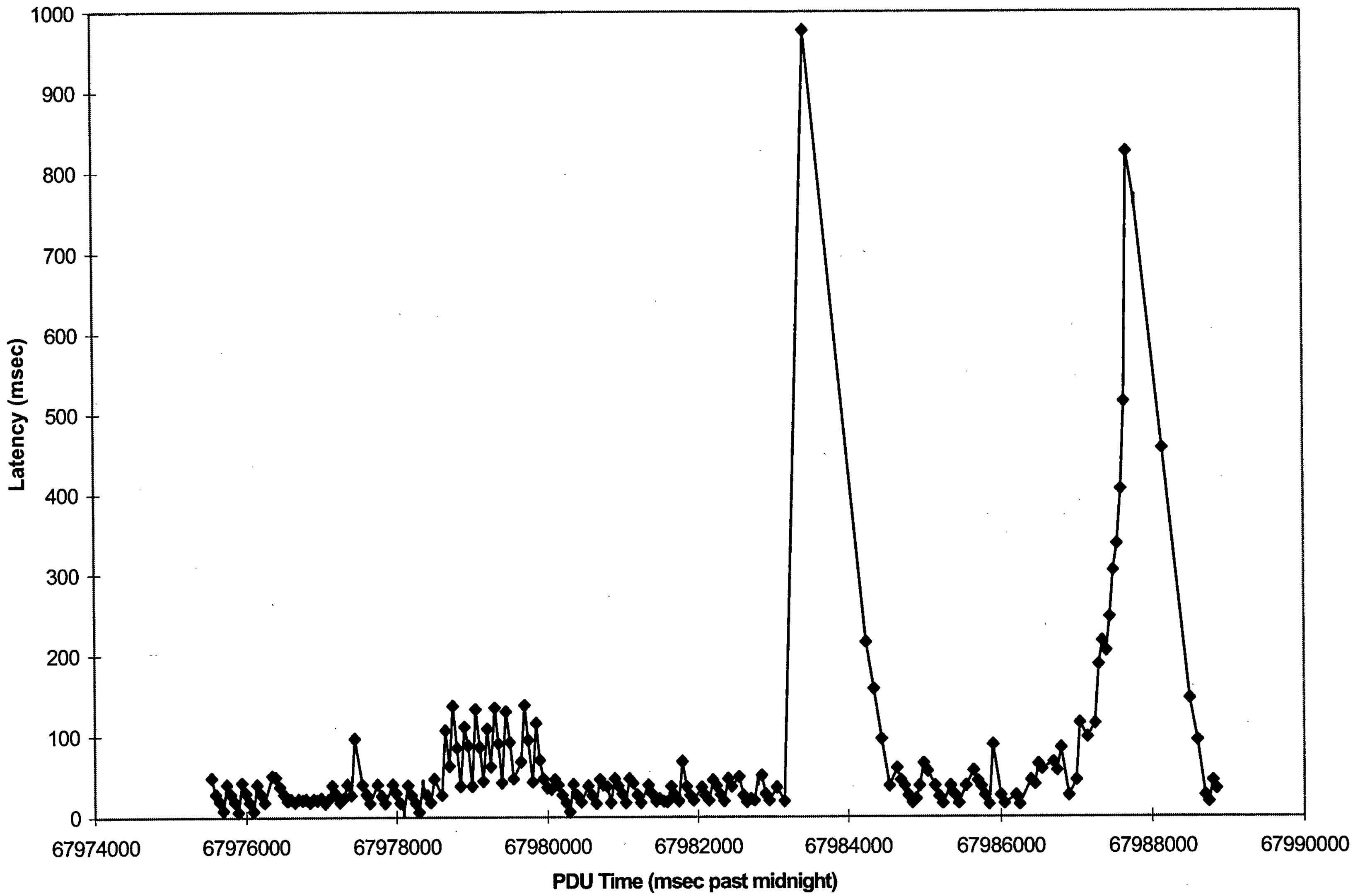


Figure 4.3.3.1-2. Latency of Shooter Entity State Data Between WSSF Simulation and SIMLAB PDU Logger (Run #51 on 8/28/96)

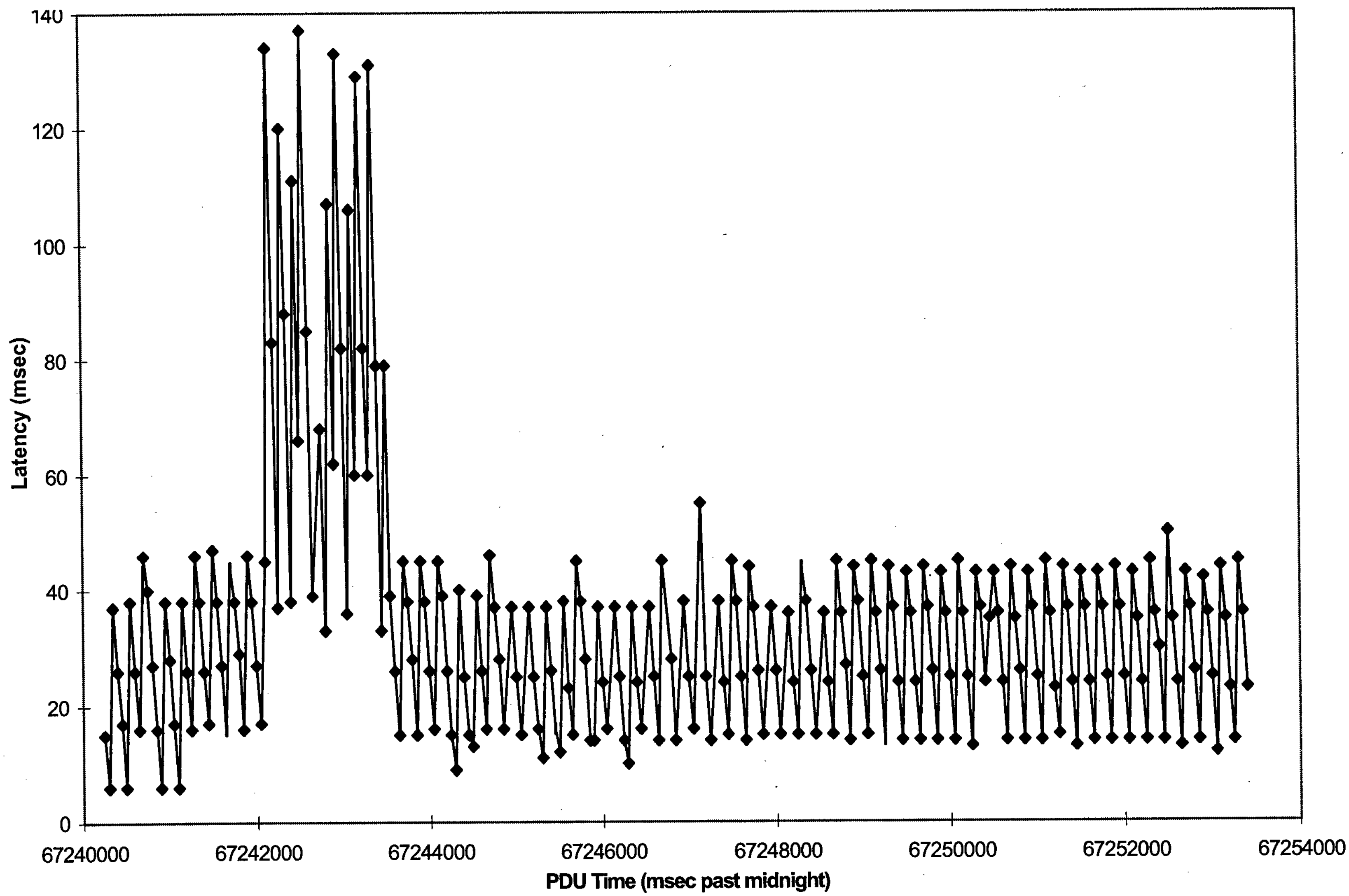


Figure 4.3.3.1-3. Latency of Shooter Entity State Data (before launch) Between WSSF Simulation and SIMLAB PDU Logger (Run #46 on 8/28/96)

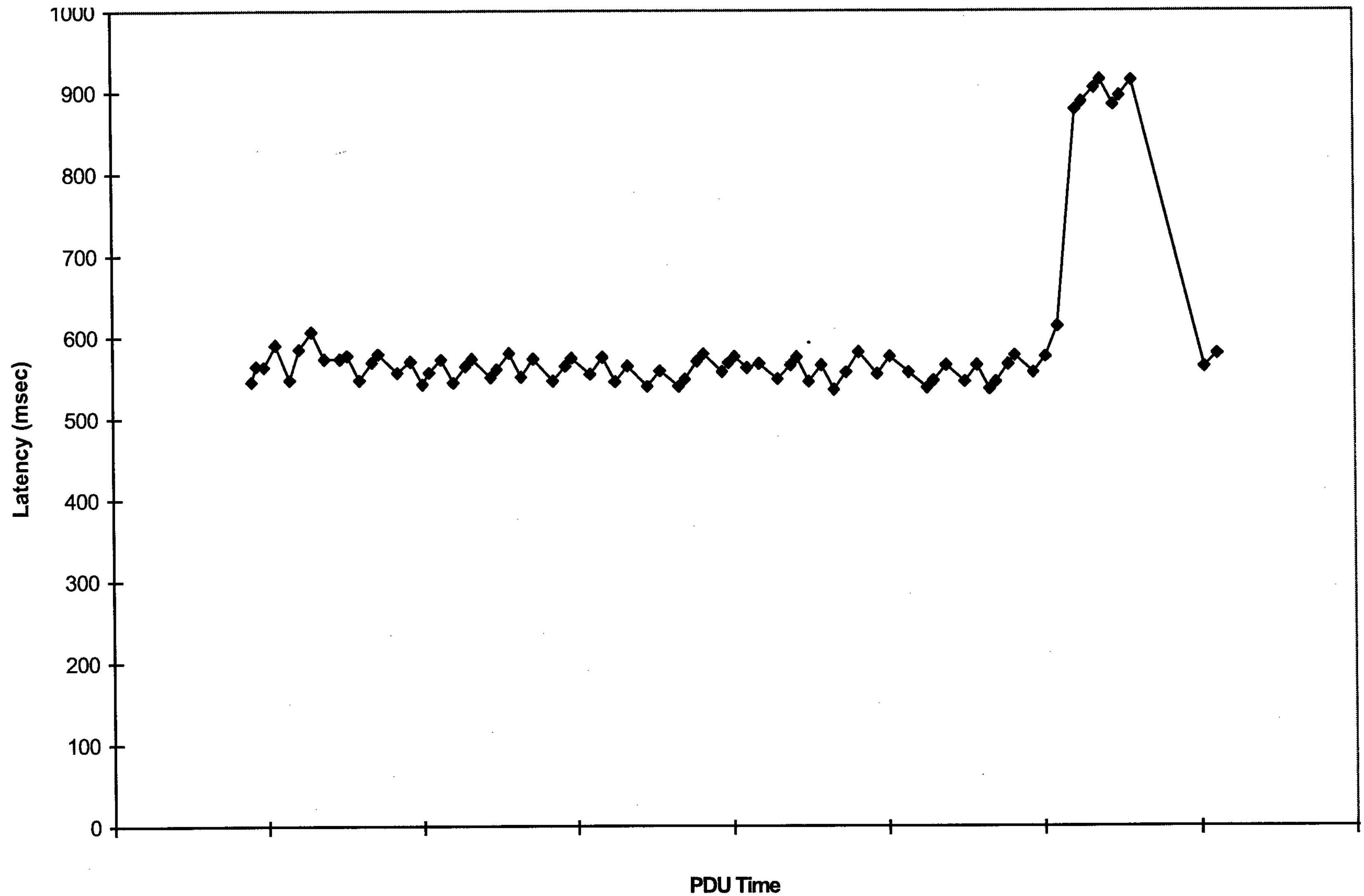


Figure 4.3.3.1-4. Latency of Missile Entity State Data (before launch) Between SIMLAB Simulation and SIMLAB PDU Logger (Run #46 on 8/28/96)

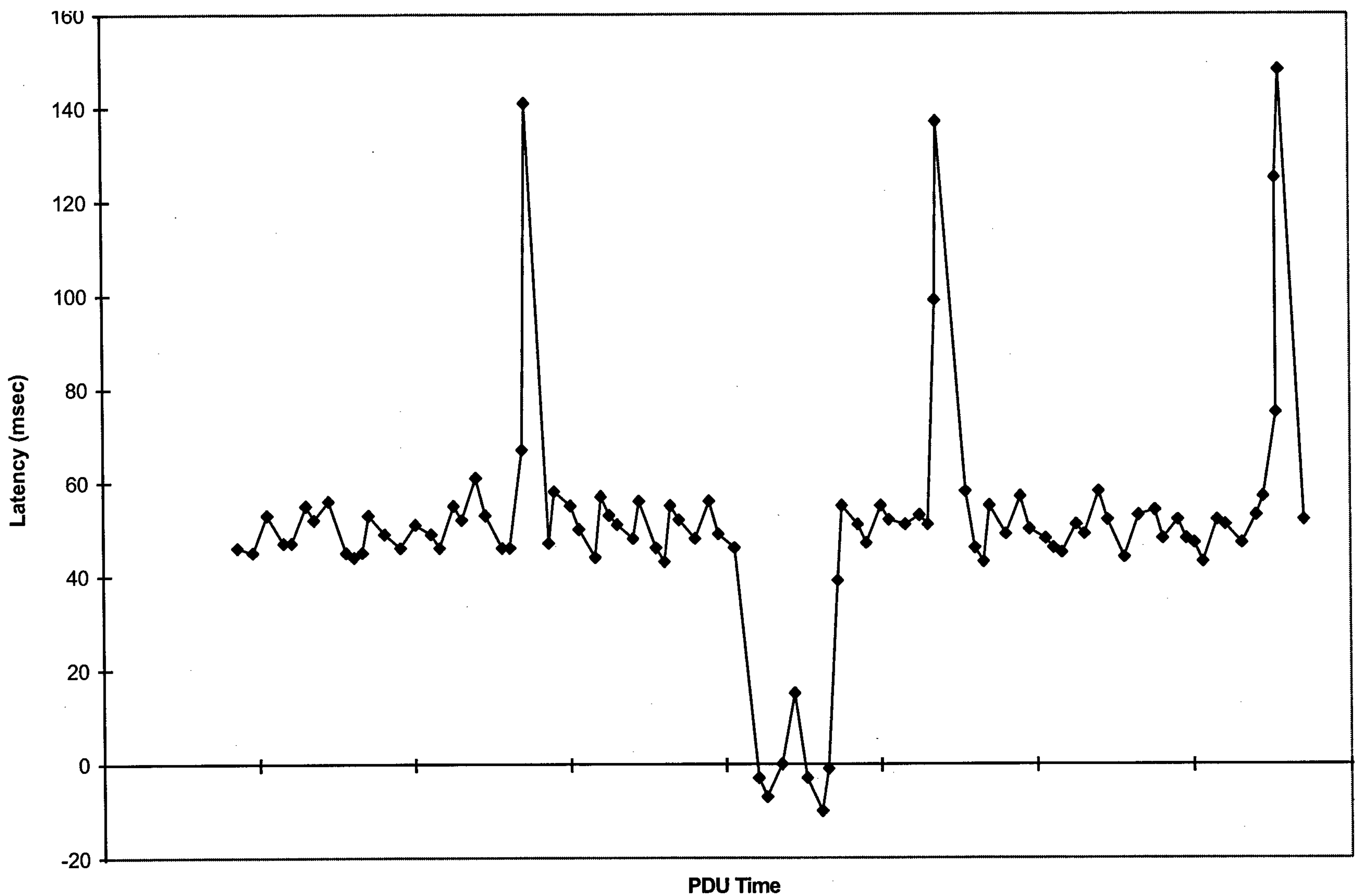


Figure 4.3.3.1-5. Latency of Missile Entity State Data Between SIMLAB Simulation and SIMLAB PDU Logger (Run #51 on 8/28/96)

The following is noted from Tables 4.3.3.1-1 and 4.3.3.1-2 and Figures 4.3.3.1-1 through 4.3.3.1-5:

- Target Entity State Data Latencies
  - -- The mean latencies of the target entity state data were consistent run-to-run, but large.
  - -- However, during a single run, the range of lat encies was relatively large (~500 ms). As Figure 4.3.3.1-1 shows, the target entity state PDUs were received at the SIMLAB in groups of 12-13, resulting in the large latency range (the range corresponds to each group). Note that the latency versus time behavior in this figure is quite repeatable.
  - -- As Table 4.3.3.1-1 shows, most of the latency contribution was between the WSIC simulation and the WSIC PDU logger. The transmission latency between the WSIC and the SIMLAB was small by comparison.

- Shooter Entity State Data Latencies
  - -- The mean latencies of the shooter entity state data were relatively small and consistent run-to-run, with the exception of Run #51.
  - -- As Figure 4.3.3.1-2 shows, the latencies of the shooter data on Run #51 became uncharacteristically large near the launch time (note that the maximum latency on this run was much larger than on other runs, but the minimum latency was about the same).
  - -- Note from Table 4.3.3.1-2 that the maximum latencies on a run were typically many (4-7) standard deviations above the mean value. On the other hand, minimum latency was usually within one standard deviation of the mean. Figure 4.3.3.1-3 shows another example of the shooter entity state data latency versus time in which the high latency values are seen to occur over a relatively short time, but not at the same time relative to launch as in Figure 4.3.3.1-2. It is hypothesized that large latencies in the shooter entity state data may have been caused by heavy computation loads in the WSSF simulation computer as the shooter prepared to launch the missile.
  - -- As Figure 4.3.3.1-3 shows, there was also some grouping of shooter entity state PDUs, but the groups were smaller than for the target entity state PDUs (3-4 per group versus 12-13).
  - -- The shooter entity state PDUs were observed to frequently "repeat," i.e., several PDUs were observed which had the same PDU time and the same entity state data, but different log times (groups of repeating PDUs as large as eight were observed). The reason for this was unclear, but may have been due to the WSSF NIU creating PDUs at a preset time before updated entity state data had been received from the WSSF simulation. Since repeating PDUs did not represent a valid update in the shooter's entity state, these were eliminated from latency calculations. Instead, repeating PDUs were treated as ADS-induced errors and analyzed under Test Objective 4-2.

- Missile Entity State Data Latencies
  - -- The mean latencies of the missile entity state data were large and consistent run-to-run, with the exception of Run #51.

-- Figure 4.3.3.1-4 shows the latency versus time for one of the high latency runs. Note that there was a relatively consistent high latency baseline with higher latency values over a short duration near the end of the missile flyout.
-- The latency versus time for Run #51 is shown in Figure 4.3.3.1-5. This run differed significantly from the other runs, having a mean latency 10%, or less, of the means for the previous runs. Note that Run #51 had negative latencies for a short duration which are physically impossible. The cause of these negative latencies may have been an error in the time stamp applied during logging in the STRICOM logger. Time stamping errors may also account for the unusually small latencies for Run #51. Since negative latencies cannot be correct, such values were eliminated from latency analyses in subsequent missions.

SUMMARY. The mean latencies of the target and missile entity state data were large and had large variations during runs with maximum latencies up to one second. The latencies of shooter entity state data had much smaller mean values by comparison, but had some high latency "spikes" (up to ~1 sec). The smaller shooter mean latencies suggested that correspondingly small latencies should also be possible for the target and missile entity state data. Most of the latency contribution was between the simulation and the NIU where PDUs were created from the raw simulation data. Transmission latencies between nodes were relatively small.

V&V Mission Latencies

Latencies for the V&V Mission (10/29/96) runs were analyzed as follows:

- The latencies of the shooter entity state data between the WSSF and the WSIC and of the target entity state data between the WSIC and the WSSF were analyzed prior to missile launch. Before launch, the shooter tracks the target, and low latencies are needed if the shooter and target are to agree on the launch conditions. The latency of the shooter data going to the WSIC was analyzed to determine implications for potential future applications in which the target and shooter are "dog fighting" before launch.
- The latencies of the target entity state data between the WSIC and the SIMLAB and of the missile entity state data between the SIMLAB and the WSIC were analyzed after missile launch and during the missile flyout to the target. The latency of the target data going to the SIMLAB was analyzed to determine how closely to real-time the missile was following the target. The latency of the missile data going to the WSIC was analyzed to determine implications for potential future applications in which the target and missile are interacting to each other in a "closed-loop" fashion.
- Tables 4.3.3.1-3 through 4.3.3.1-6 present a sampling of runs during the V&V Mission, and include entries for the latency characteristics between the originating simulation and the logger at the originating simulation node, the latencies between the logger at the transmitting NIU and the logger at the receiving NIU, and the net latencies between the originating simulation and the receiving NIU. Latencies into the receiving simulation were only analyzed at launch for this mission and will be discussed in Section 4.3.3.2.
- Figures 4.3.3.1-6 through 4.3.3.1-10 show latency as a function of PDU time for several entity/run combinations.

Table 4.3.3.1-3. Latencies (in msec) for Target Entity State Data (before launch) From WSIC to WSSF (10/29/96)

	WSIC Sim to WSIC Logger				WSIC Logger to WSSF Logger				WSIC Sim to WSSF Logger			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
3	23.5	14.6	3	52	17.5	4.7	1	40	41.0	14.3	20	68
5	23.2	14.6	2	52	18.1	4.9	1	68	41.3	14.6	20	79
10	24.4	14.1	3	52	21.1	14.9	2	128	45.5	20.6	18	134
15	23.9	15.0	1	70	20.8	17.3	5	126	44.7	21.3	18	155
19	23.2	13.9	2	52	17.2	5.0	3	50	40.5	14.7	18	82
23	23.5	14.5	2	65	19.3	14.8	3	126	42.8	20.0	18	134
Average of Means	23.6	14.4			19.0	10.3			42.6			
Std Dev of Means	0.5				1.7				2.1			

Table 4.3.3.1-4. Latencies (in msec) for Shooter Entity State Data (before launch) From WSSF to WSIC (10/29/96)

	WSSF Sim to WSSF Logger				WSSF Logger to WSIC Logger				WSSF Sim to WSIC Logger			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
3	52.1	132.4	23	1096	17.8	11.0	11	88	70.0	132.3	37	1111
5	59.9	13.2	41	112	17.2	5.9	11	66	77.1	14.1	56	129
10	434.4	37.1	383	674	26.4	24.4	2	149	460.8	45.1	435	721
15	629.1	65.5	560	914	20.4	17.5	12	122	649.5	66.4	576	932
19	705.5	65.6	676	1090	18.8	10.1	5	109	724.3	65.8	692	1101
23	727.5	23.0	670	781	23.0	17.4	8	125	750.5	29.8	688	892
Average of Means	434.8	56.1			20.6	14.3			455.3	58.9		
Std Dev of Means	311.1				3.5				312.7			

Table 4.3.3.1-5. Latencies (in msec) for Target Entity State Data (during missile flyout) From WSIC to SIMLAB (10/29/96)

	WSIC Sim to WSIC Logger				WSIC Logger to SIMLAB Logger				WSIC Sim to SIMLAB Logger			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
3	23.1	14.2	3	45	16.2	2.7	13	30	39.3	14.2	18	68
5	23.4	15.3	3	59	17.0	5.0	1	46	40.4	15.9	19	88
10	24.2	14.0	3	45	15.4	2.8	13	29	39.6	14.1	19	72
15	24.6	14.6	1	60	15.3	3.1	5	30	39.9	14.6	17	66
19	23.1	13.7	3	45	16.3	2.3	4	22	39.3	13.3	19	65
23	23.1	14.8	2	58	24.1	22.1	2	106	47.2	27.2	18	148
Average of Means	23.6	14.4			17.4	6.3			41.0	16.5		
Std Dev of Means	0.7				3.4				3.1			

Table 4.3.3.1-6. Latencies (in msec) for Missile Entity State Data From SIMLAB to WSIC (10/29/96)

	SIMLAB Sim to SIMLAB Logger				SIMLAB Logger to WSIC Logger				SIMLAB Sim to WSIC Logger			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
3	78.1	16.4	67	186	17.0	8.1	2	65	95.1	17.8	82	203
5	253.7	9.3	238	288	16.6	6.2	1	55	270.3	10.3	252	304
10	19.0	14.1	7	115	21.3	19.2	2	154	40.3	23.3	23	181
15	12.7	4.5	5	30	16.0	3.9	3	39	28.7	5.5	20	55
19	487.0	79.9	433	724	18.9	13.7	8	118	505.9	79.9	448	739
23	559.2	88.8	506	850	24.4	24.4	12	127	583.7	93.6	520	932
Average of Means	235.0	35.5			19.0	12.6			254.0	38.4		
Std Dev of Means	240.7				3.3				242.5			

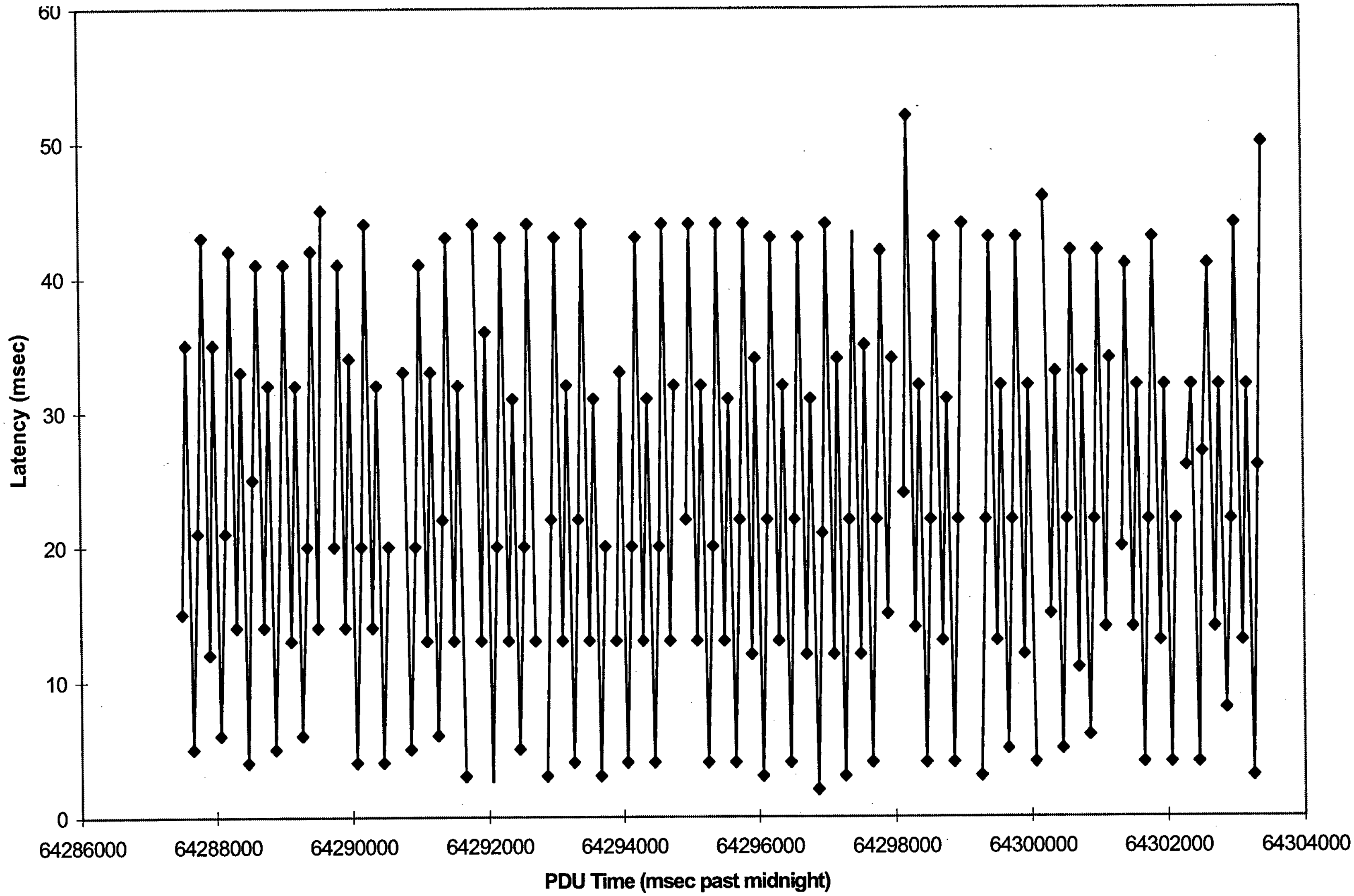


Figure 4.3.3.1-6. Latency of Target Entity State Data (before launch) Between WSIC Simulation and WSIC PDU Logger (Run #19 on 10/29//96)

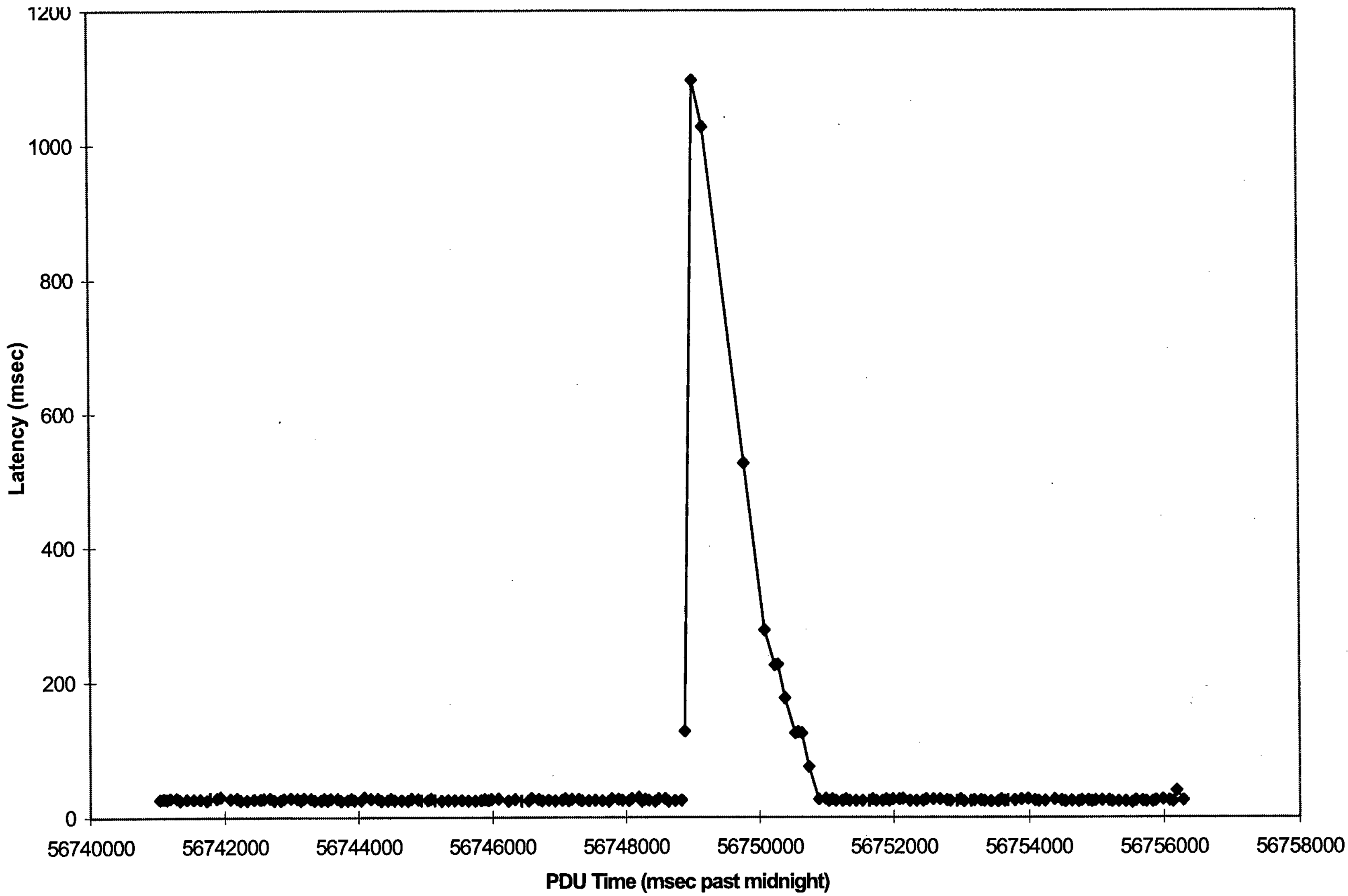


Figure 4.3.3.1-7. Latency of Shooter Entity State Data (before launch) Between WSSF Simulation and WSSF PDU Logger (Run #3 on 10/29/96)

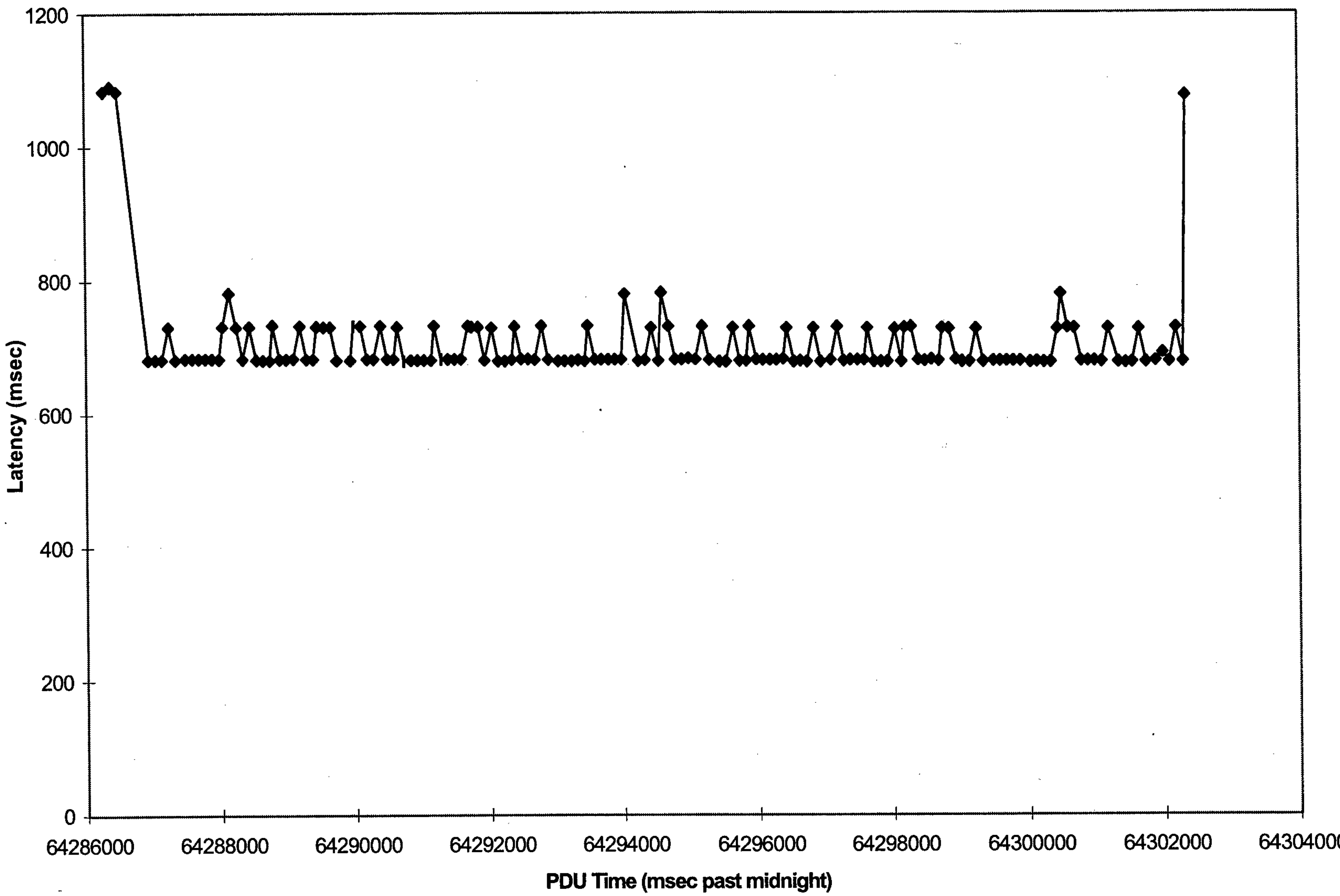


Figure 4.3.3.1-8. Latency of Shooter Entity State Data (before launch) Between WSSF Simulation and WSSF PDU Logger (Run #19 on 10/29/96)

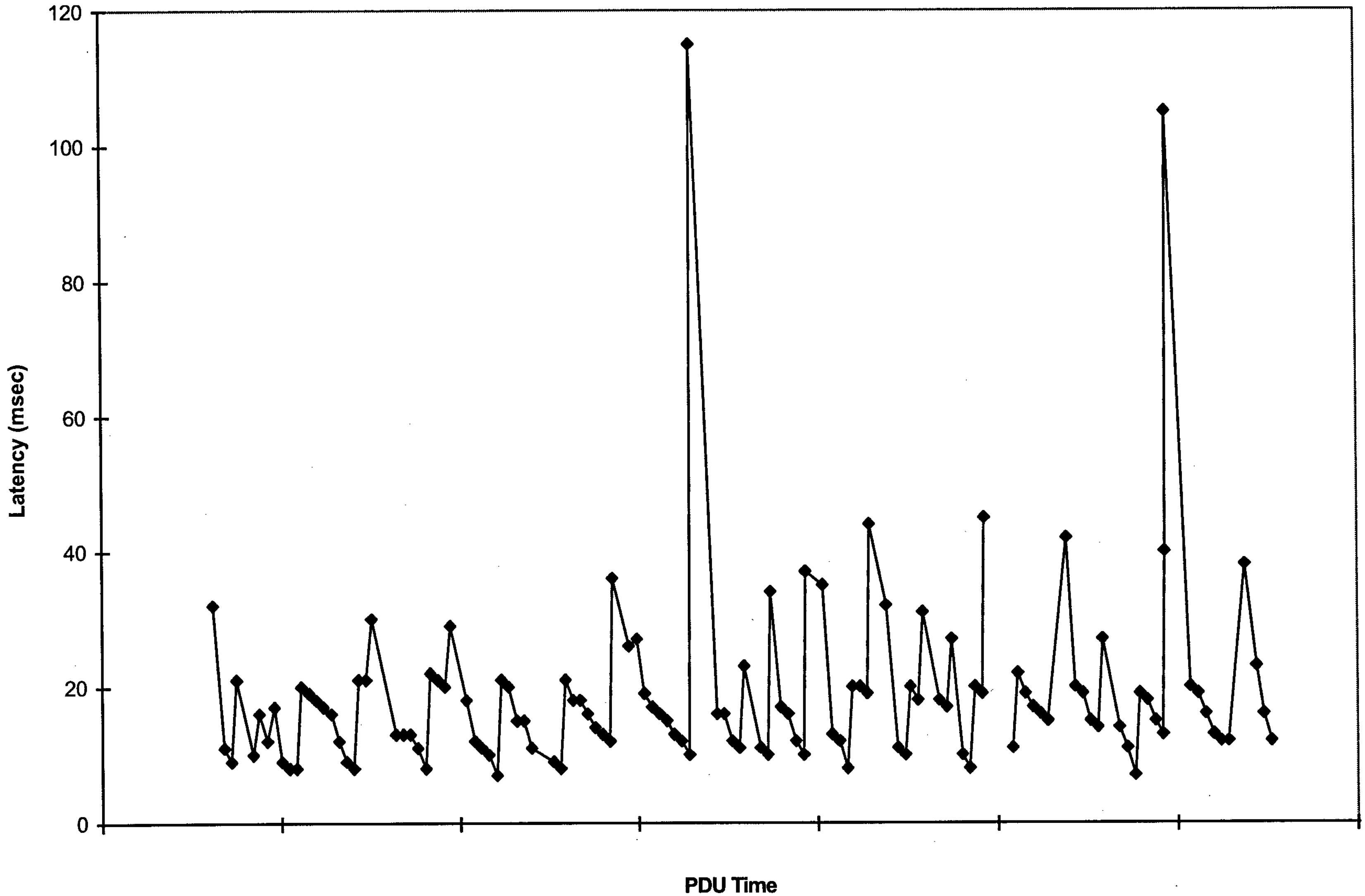


Figure 4.3.3.1-9. Latency of Missile Entity State Data Between SIMLAB Simulation and SIMLAB PDU Logger (Run #10 on 10/29/96)

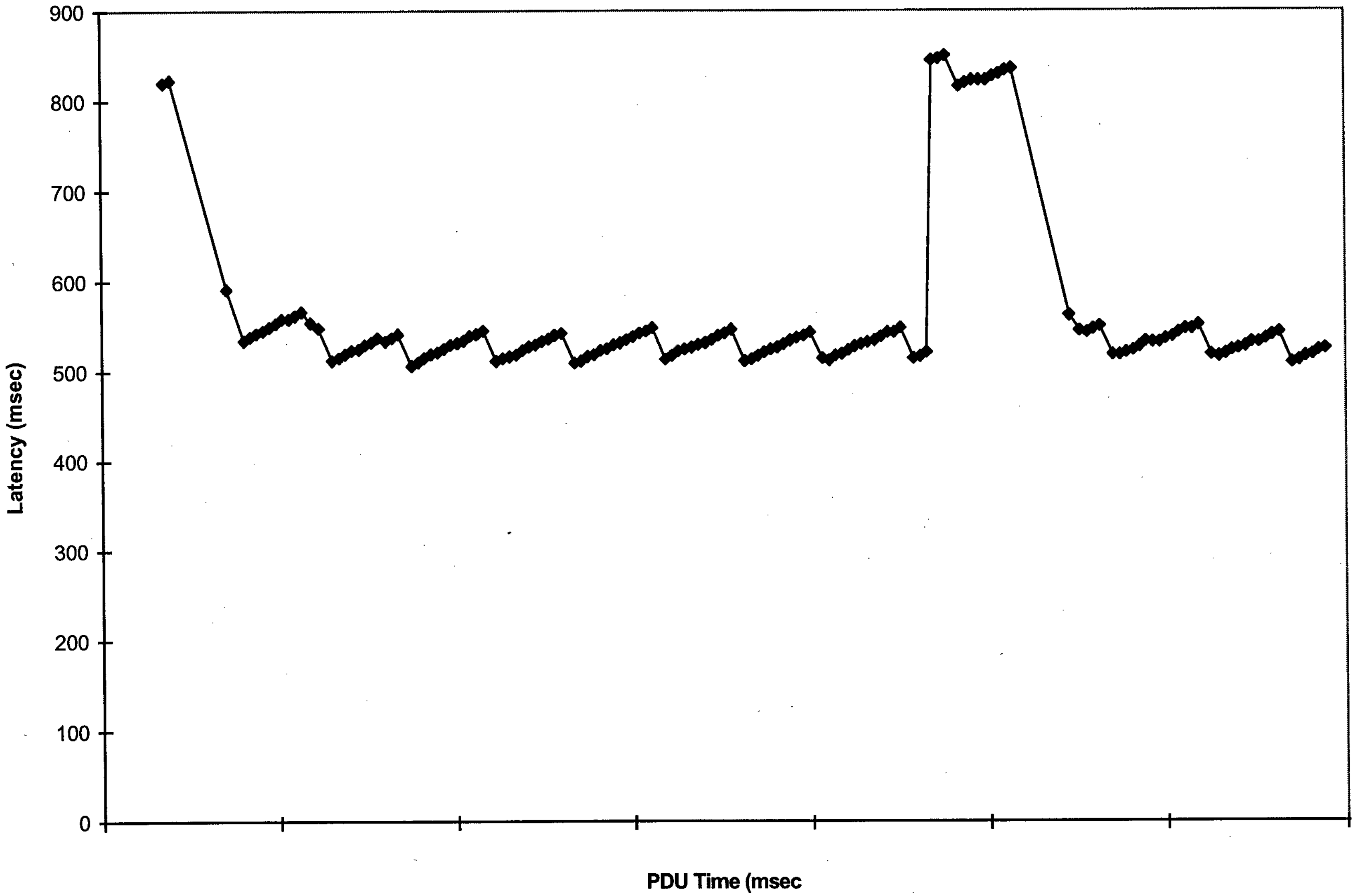


Figure 4.3.3.1-10. Latency of Missile Entity State Data Between SIMLAB Simulation and SIMLAB PDU Logger (Run #23 on 10/29/96)

The following is noted from Tables 4.3.3.1-3 through 4.3.3.1-6 and Figures 4.3.3.1-6 through 4.3.3.1-10:

- Target Entity State Data Latencies
  - -- The mean latencies of the target entity state data were small and consistent run-to-run (Tables 4.3.3.1-3 and 4.3.3.1-5). The mean latencies between the WSIC simulation and the WSIC PDU logger were ~10% of the values from the Mission Rehearsal. Also, the mean latencies between the WSIC PDU logger and the SIMLAB PDU logger were about half of the values from the Mission Rehearsal.
  - -- As Figure 4.3.3.1-6 shows, there was still grouping of the target entity state PDUs, although the groups were smaller than in the Mission Rehearsal (2-3 per group versus 12-13). Part of the reason for the smaller number per group may have been that the target entity state PDUs were created at a lower rate compared to the Mission Rehearsal (12.5 Hz versus 25 Hz).
  - -- As Tables 4.3.3.1-4 and 4.3.3.1-5 show, the mean latency between the WSIC simulation and the WSIC PDU logger was about the same as the mean transmission latency between PDU loggers. Also, the mean latency between the WSIC logger and the WSSF logger was about the same as between all other pairs of loggers.

- Shooter Entity State Data Latencies
  - -- The mean latencies of the shooter entity state data were large and inconsistent run-to-run (Table 4.3.3.1-4). Note that the mean latency values generally increased as the runs progressed. The mean latencies from the earlier V&V Mission runs were comparable to those from the Mission Rehearsal, but those from the later runs were more than ten times larger.
  - -- Most of the runs still exhibited the large latency "spikes," as in the Mission Rehearsal. Again, these high latency values occurred over relatively short durations (200-400 msec) at various times before missile launch.
  - -- Figures 4.3.3.1-7 and 4.3.3.1-8 compare shooter entity state data latencies for an early low-mean-latency run with those for a later high-mean-latency run. Note that there was a relatively consistent latency baseline on each run which increased. However, the value of the latency "spikes" were about the same for the two runs.

- Missile Entity State Data Latencies
  - -- The mean latencies of the missile entity state data were also large and inconsistent run-to-run (Table 4.3.3.1-6). However, unlike the shooter entity state data latencies, the mean latencies of the missile data did not show a progressive increase. The range of mean latencies was somewhat smaller than that for the Mission Rehearsal.
  - -- Figures 4.3.3.1-9 and 4.3.3.1-10 compare missile entity state data latencies for a low-mean-latency run with those for a high-mean-latency run. Note that there was a relatively consistent latency baseline on each run which increased. Also, note the latency "spikes."
  - -- Figure 4.3.3.1-10 shows that th e missile entity state PDUs were "bunching" on some of the runs with 10-12 PDUs per group.

SUMMARY. The mean latencies of the target entity state data were much smaller than in the Mission Rehearsal, while those for the shooter were much larger. The cause(s) of these changes was not obvious, since there were changes in both the code used to program the NIUs and in the NIU parameters. The shooter entity state data still exhibited high latency "spikes" (up to ~1 sec). The shooter and missile entity state data both had large variations in the mean latency run-to-run. These variations achieved in an uncontrolled fashion what the Latency Mission test method was to achieve in a controlled fashion, so that data from this mission could be used to evaluate the effects of latency on test results. Transmission latencies between the simulation nodes were all relatively small, and the mean value was about 20 msec for all the node pairs.

Parametric Study Mission Latencies

Subsequent to the V&V Mission, it was determined that resetting the NIUs at each node resulted in lower latencies between the simulation at the node and the DIS PDU logger. Apparently, the NIU performance degraded as the number of runs increased, as Table 4.3.3.1-4 suggests. Also, the improvement in latencies between the SIMLAB simulation and the SIMLAB DIS PDU logger (e.g., Run #10 in Table 4.3.3.1-6) seemed to be related to resetting the SIMLAB NIU. Hence, in the Parametric Study Mission, the WSSF and SIMLAB NIUs were reset before each run (the WSIC NIU did not require resetting).

Also, the latencies seemed to be affected by the choice of NIU parameters. During the linked laboratory time on 11/12/96, the best configurations for the NIUs were determined to be as given in Table 4.3.3.1-7. These settings were used in the Parametric Study Mission.

Table 4.3.3.1-7. NIU Configurations for the Parametric Study Mission

NIU Parameter	WSIC	WSSF	SIMLAB
Timeout	50 msec (20 Hz)	50 msec (20 Hz)	50 msec (20 Hz)
Dead Reckoning	No	Yes	Yes
Iteration Rate (NIU Input Rate)	40 Hz	40 Hz	40 Hz
Update Rate (NIU Output Rate)	20 Hz	20 Hz	20 Hz

Latencies for the Parametric Study Mission runs were analyzed as for the V&V Mission.

- Tables 4.3.3.1-8 through 4.3.3.1-11 give latency characteristics for all complete V2 runs, and include entries for the latencies between the originating simulation and the logger at the originating simulation node, the latencies between the logger at the transmitting NIU and the logger at the receiving NIU, and the net latencies between the originating simulation and the receiving NIU.
- Latencies into the receiving simulation were determined for target data into the WSSF and the SIMLAB simulations by matching entity state data values in the PDUs with those in the simulation frames. Results are in Tables 4.3.3.1-12 and 4.3.3.1-13.
- Figures 4.3.3.1-11 through 4.3.3.1-24 show latency as a function of PDU time and latency frequency histograms for several entity/run combinations.

Table 4.3.3.1-8. Latencies (in msec) for Target Entity State Data (before launch) From WSIC to WSSF (11/19/96)

	WSIC Sim to WSIC Logger				WSIC Logger to WSSF Logger				WSIC Sim to WSSF Logger			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
9	11.1	9.1	3	105	16.9	4.5	2	42	28.0	9.8	19	122
10	10.5	5.3	3	38	16.5	4.9	1	64	27.1	6.0	19	69
12	8.6	5.8	2	45	20.3	13.6	2	127	28.8	15.4	18	137
18	9.4	5.3	3	35	19.8	5.2	1	58	29.2	6.7	20	72
19	10.1	5.9	2	33	24.3	18.6	1	132	34.3	18.9	20	142
22	9.5	4.9	2	23	17.7	1.6	7	27	27.2	5.2	19	40
Average of Means	9.9	6.1			19.2	8.1			29.1	10.3		
Std Dev of Means	0.9				2.9				2.7			

Table 4.3.3.1-9. Latencies (in msec) for Shooter Entity State Data (before launch) From WSSF to WSIC (11/19/96)

	WSSF Sim to WSSF Logger				WSSF Logger to WSIC Logger				WSSF Sim to WSIC Logger			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
9	55.0	14.6	12	75	20.2	11.5	3	96	75.0	18.3	29	154
10	51.0	5.2	12	76	21.8	15.3	8	123	72.8	16.3	28	176
12	20.0	9.2	12	46	20.6	16.5	5	123	40.6	17.7	26	138
18	59.2	8.9	14	111	16.5	11.2	1	98	75.9	14.2	28	158
19	51.0	1.9	48	65	19.9	19.0	1	124	70.7	19.0	61	175
22	48.2	1.9	44	54	19.3	18.6	9	203	67.8	18.6	58	247
Average of Means	47.4	6.9			19.7	15.3			67.1	17.4		
Std Dev of Means	13.9				1.8				13.3			

Table 4.3.3.1-10. Latencies (in msec) for Target Entity State Data (during missile flyout) From WSIC to SIMLAB (11/19/96)

	WSIC Sim to WSIC Logger				WSIC Logger to SIMLAB Logger				WSIC Sim to SIMLAB Logger			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
9	9.8	4.8	3	20	13.1	3.1	7	37	23.6	5.4	16	55
10	10.3	5.0	3	23	13.9	3.3	6	31	24.1	5.8	16	44
12	8.6	4.8	2	25	14.9	3.9	2	40	23.2	6.0	15	55
18	9.3	5.1	3	25	16.2	5.6	1	46	25.4	6.6	17	51
19	10.2	6.6	2	56	30.0	30.2	6	125	39.4	30.4	17	139
22	9.6	5.2	2	24	14.7	3.9	1	39	24.3	6.4	16	54
Average of Means	9.6	5.3			17.2	8.3			26.7	10.1		
Std Dev of Means	0.6				6.4				6.3			

Table 4.3.3.1-11. Latencies (in msec) for Missile Entity State Data From SIMLAB to WSIC (11/19/96)

	SIMLAB Sim to SIMLAB Logger				SIMLAB Logger to WSIC Logger				SIMLAB Sim to WSIC Logger			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
9	7.3	4.6	1	32	19.7	12.8	11	128	26.9	13.3	18	134
10	5.5	2.7	2	12	22.6	15.2	14	122	28.1	15.2	18	127
12	56.9	21.3	39	118	21.4	17.8	3	117	79.3	27.0	55	166
18	11.5	13.6	5	133	17.9	9.8	2	94	29.4	16.4	21	150
19	8.7	4.2	5	29	29.4	28.8	1	122	38.0	28.7	19	130
22	10.7	4.1	5	31	22.9	25.3	3	192	33.5	25.8	24	213
Average of Means	16.8	8.4			22.3	18.3			39.2	21.1		
Std Dev of Means	19.8				4.0				20.0			

Table 4.3.3.1-12. Latencies (in msec) for Target Entity State Data (before launch) From WSIC into WSSF Simulation (11/19/96)

Run #	WSSF Logger to WSSF Sim				WSIC Sim to WSSF Sim			
	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
9	20.6	25.3	1	162	47.6	26.5	30	190
10	38.9	14.3	27	92	66.4	14.5	60	124
12	51.2	51.5	1	347	77.7	50.0	21	369
18	34.9	12.0	18	98	63.5	12.8	43	120
19	33.9	11.2	14	86	63.9	9.7	49	111
22	49.0	28.4	3	187	78.1	29.6	27	220
Average of Means	38.1	23.8			66.2	23.9		
Std Dev of Means	11.2				11.2			

Table 4.3.3.1-13. Latencies (in msec) for Target Entity State Data (after launch) From WSIC into SIMLAB Simulation (11/19/96)

Run #	SIMLAB Logger to SIMLAB Sim				WSIC Sim to SIMLAB Sim			
	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
9	47.1	47.2	12	328	70.3	46.3	39	346
10	30.5	30.1	6	215	54.0	30.3	25	235
12	53.0	36.0	7	227	76.0	36.7	25	254
18	47.5	51.8	2	362	71.4	51.8	25	384
19	52.3	45.7	2	301	83.8	49.0	28	328
22	39.9	31.4	3	210	64.6	32.9	27	240
Average of Means	45.1	40.4			70.0	41.2		
Std Dev of Means	8.5				10.2			

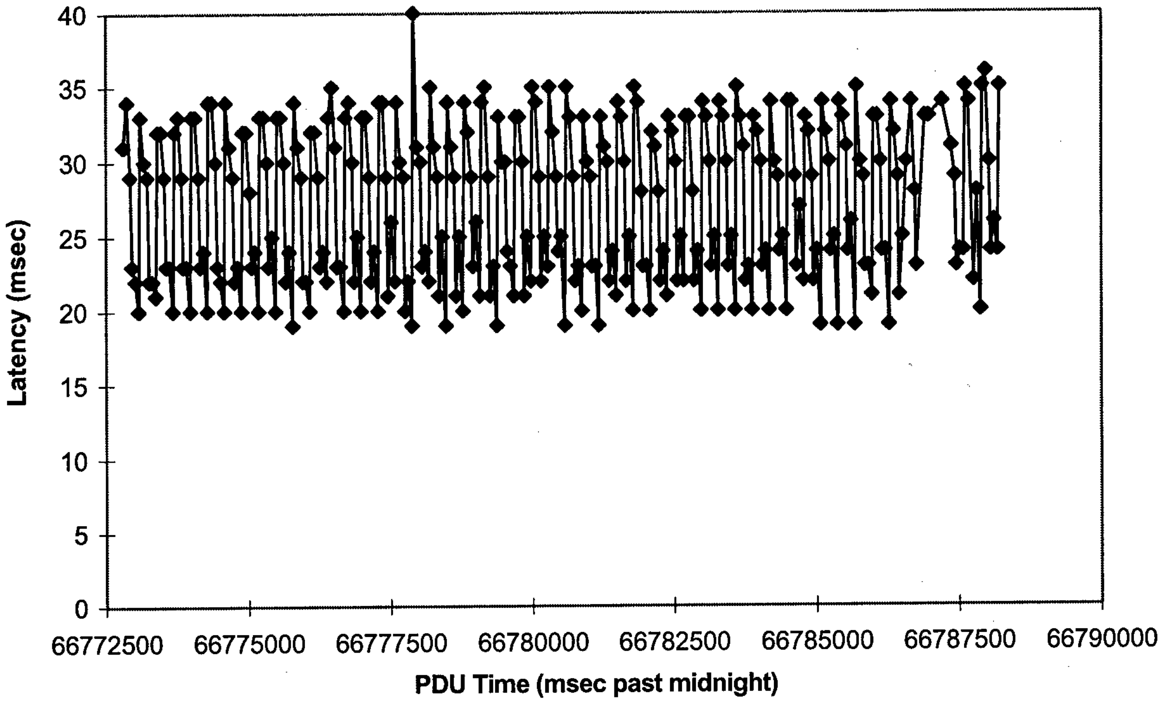


Figure 4.3.3.1-11a. Latency of Target Entity State Data (before launch) Between WSIC Simulation and WSSF PDU Logger (Run #22 on 11/19/96)

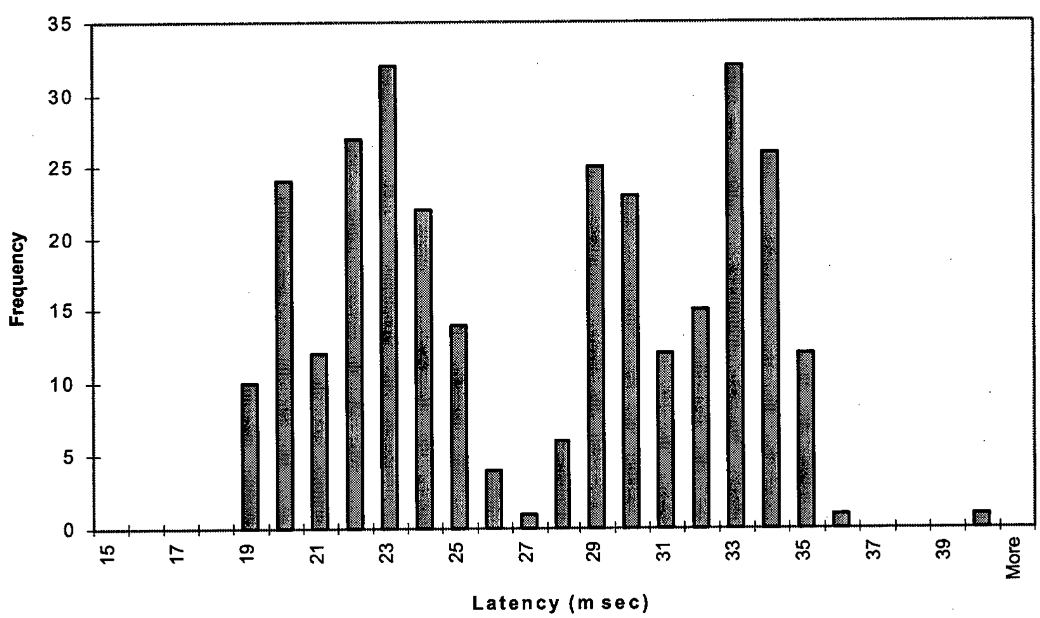


Figure 4.3.3.1-11b. Frequency Histogram of Latency of Target Entity State Data (before launch) Between WSIC Simulation and WSSF PDU Logger (Run #22 on 11/19/96)

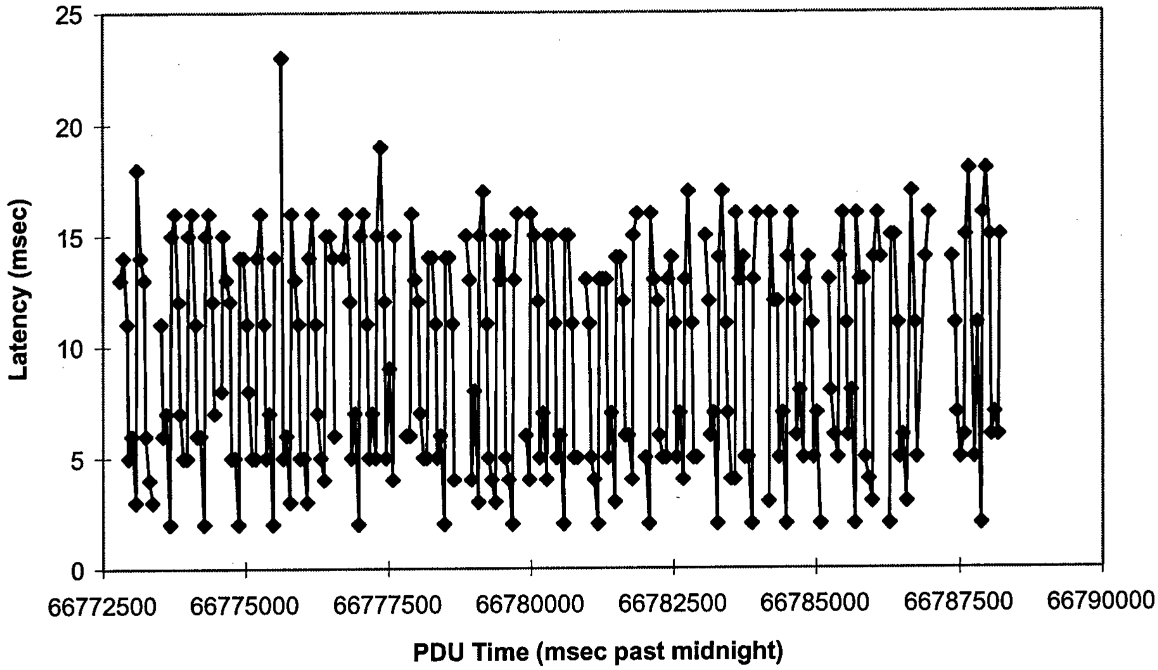


Figure 4.3.3.1-12. Latency of Target Entity State Data (before launch) Between WSIC Simulation and WSIC PDU Logger (Run #22 on 11/19/96)

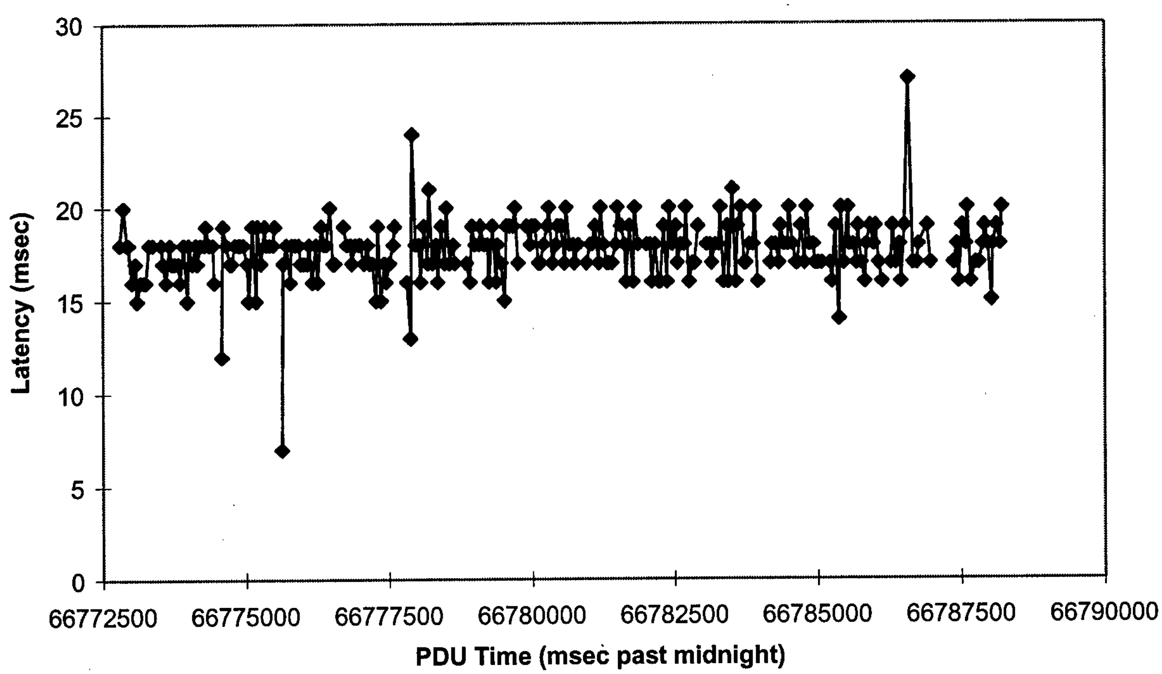


Figure 4.3.3.1-13. Latency of Target Entity State Data (before launch) Between WSIC PDU Logger and WSSF PDU Logger (Run #22 on 11/19/96)

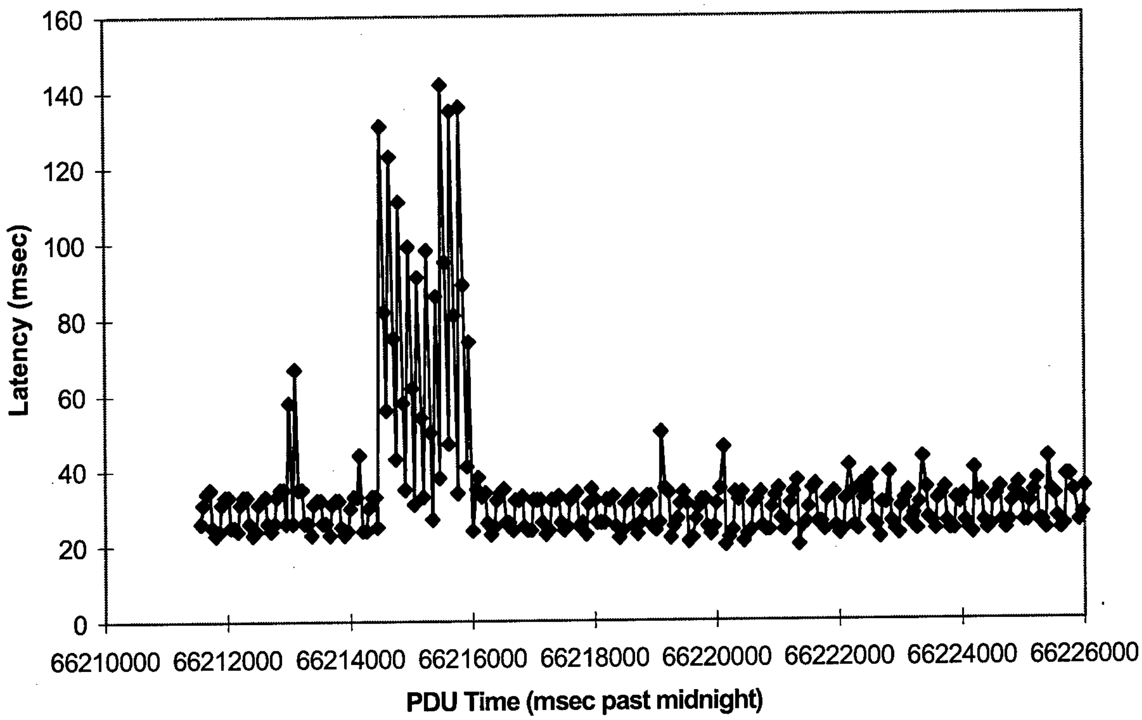


Figure 4.3.3.1-14a. Latency of Target Entity State Data (before launch) Between WSIC Simulation and WSSF PDU Logger (Run #19 on 11/19/96)

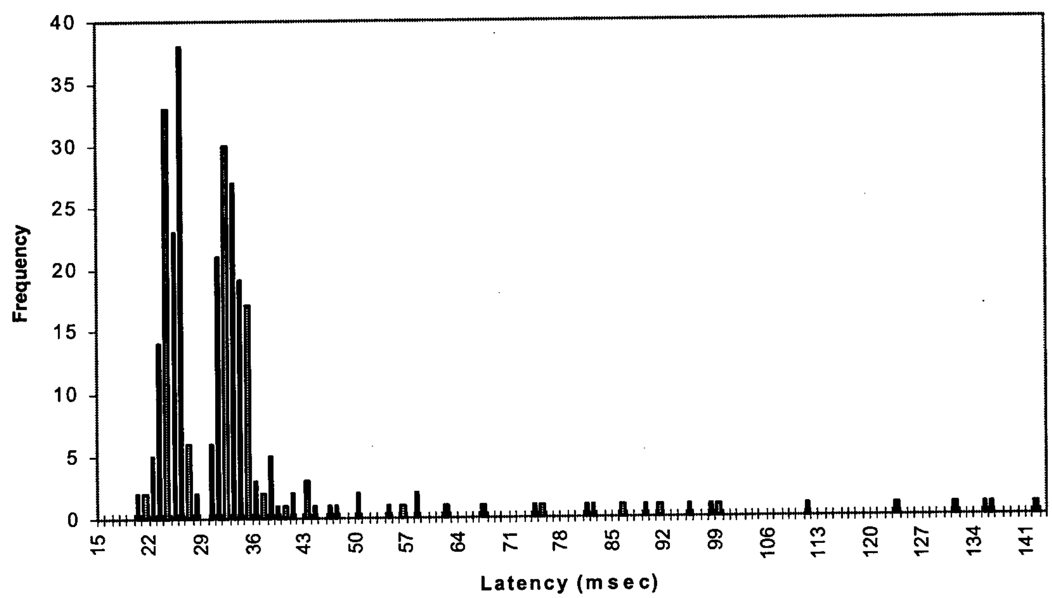


Figure 4.3.3.1-14b. Frequency Histogram of Latency of Target Entity State Data (before launch) Between WSIC Simulation and WSSF PDU Logger (Run #19 on 11/19/96)

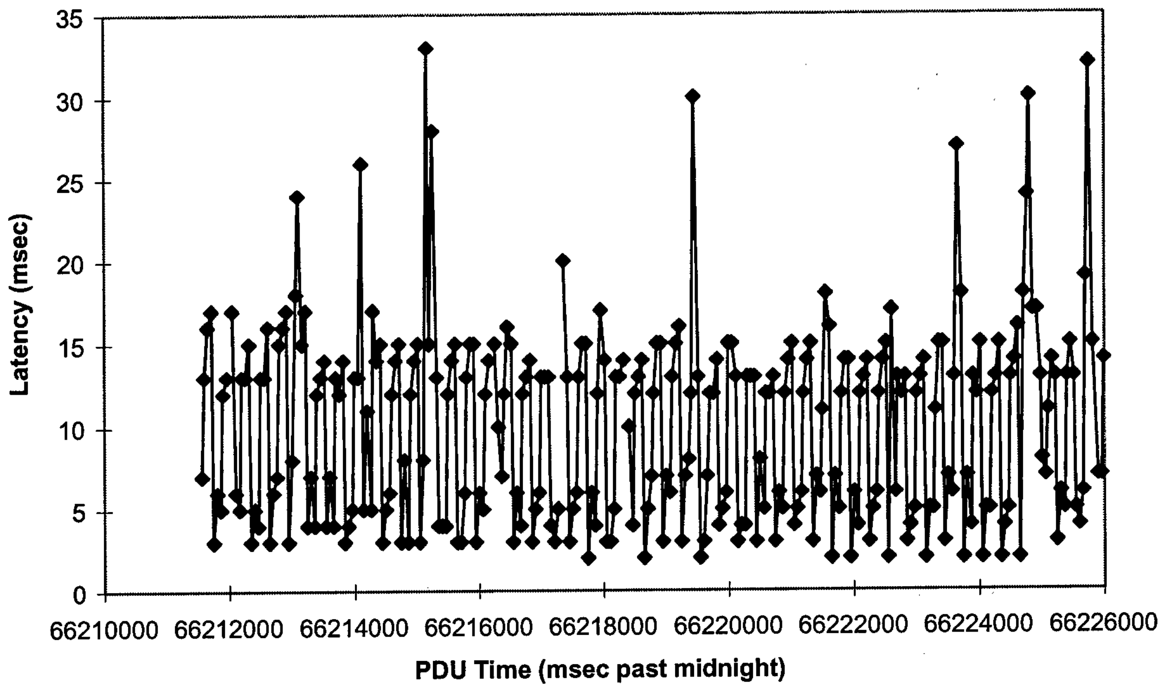


Figure 4.3.3.1-15. Latency of Target Entity State Data (before launch) Between WSIC Simulation and WSIC PDU Logger (Run #19 on 11/19/96)

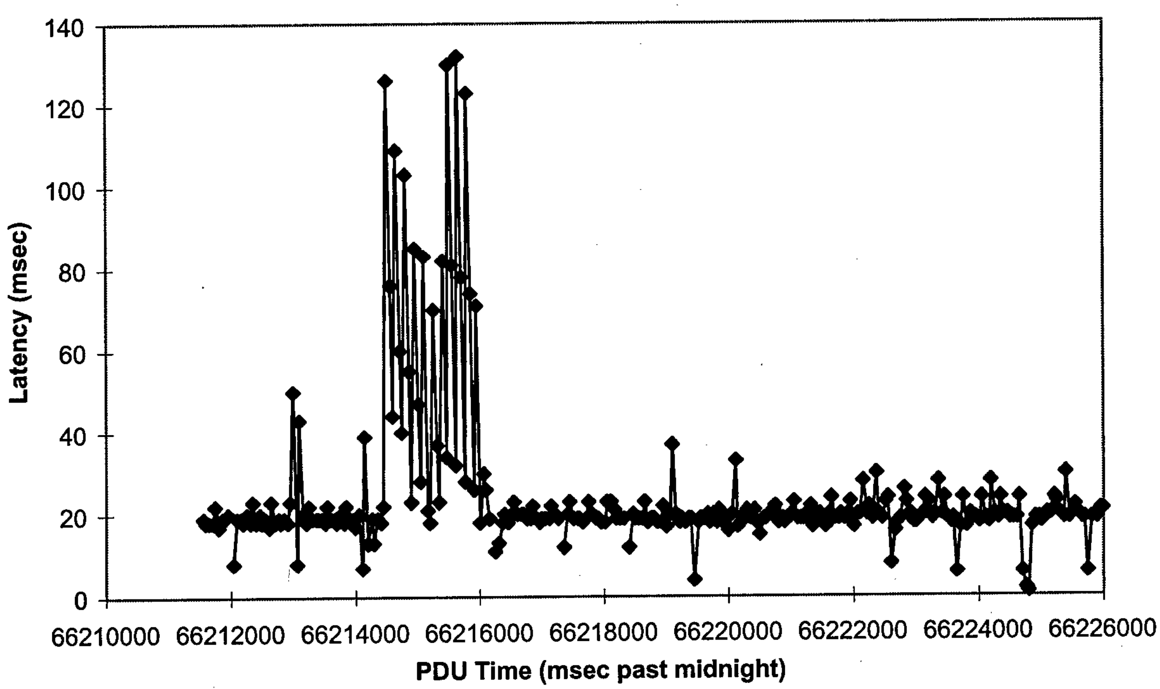


Figure 4.3.3.1-16. Latency of Target Entity State Data (before launch) Between WSIC PDU Logger and WSSF PDU Logger (Run #19 on 11/19/96)

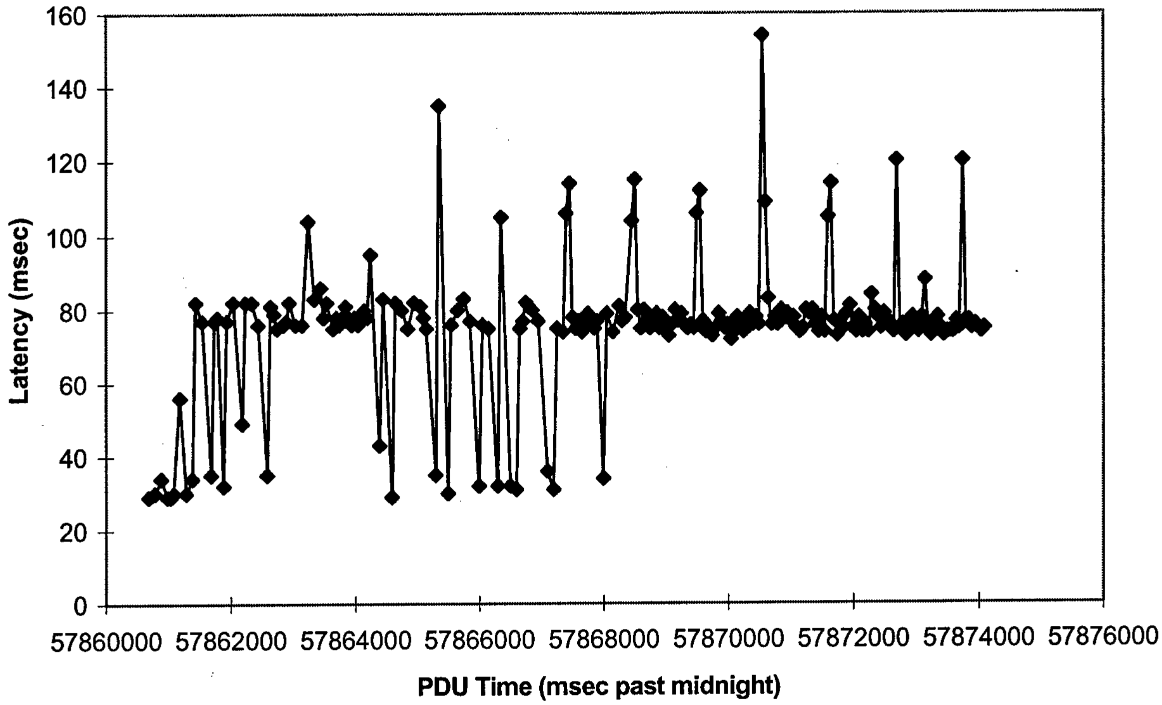


Figure 4.3.3.1-17a. Latency of Shooter Entity State Data (before launch) Between WSSF Simulation and WSIC PDU Logger (Run #9 on 11/19/96)

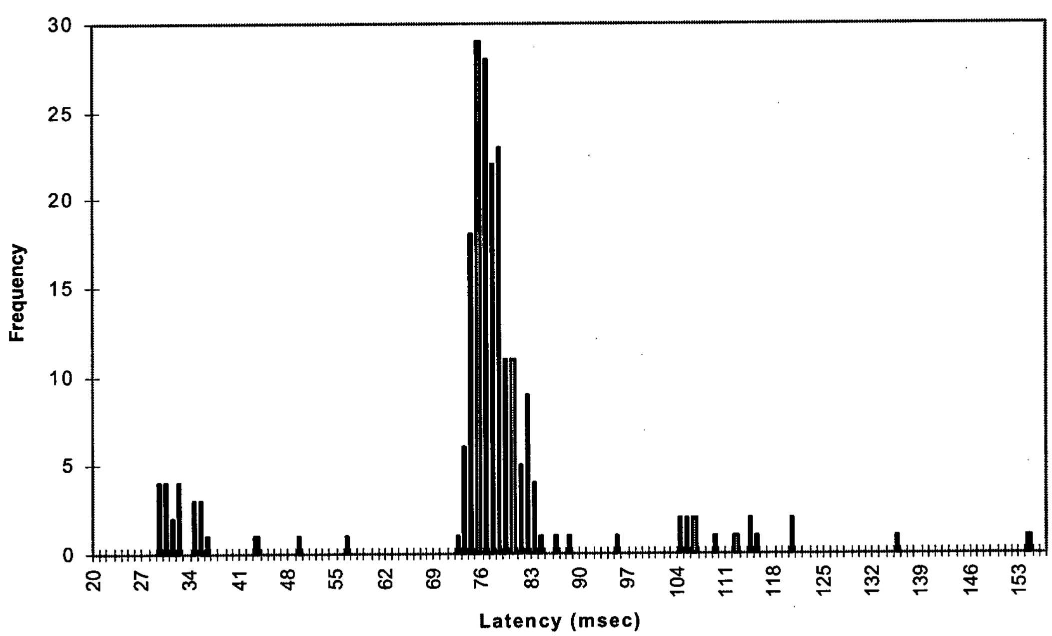


Figure 4.3.3.1-17b. Frequency Histogram of Latency of Shooter Entity State Data (before launch) Between WSSF Simulation and WSIC PDU Logger (Run #9 on 11/19/96)

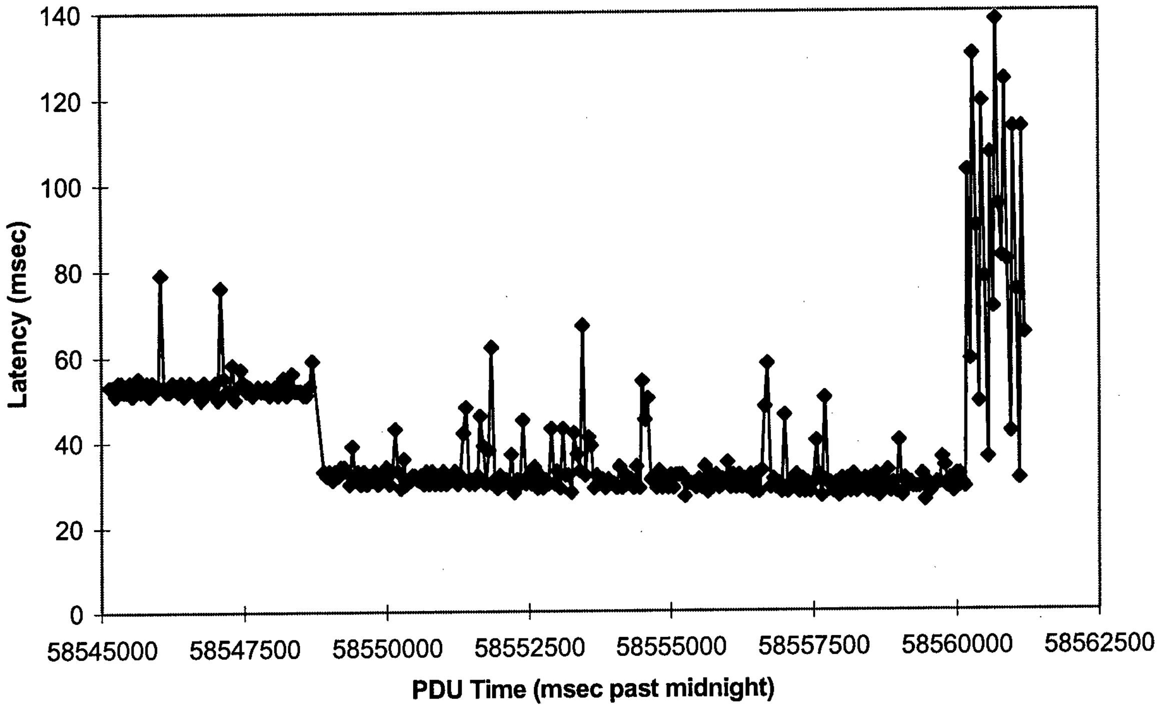


Figure 4.3.3.1-18a. Latency of Shooter Entity State Data (before launch) Between WSSF Simulation and WSIC PDU Logger (Run #12 on 11/19/96)

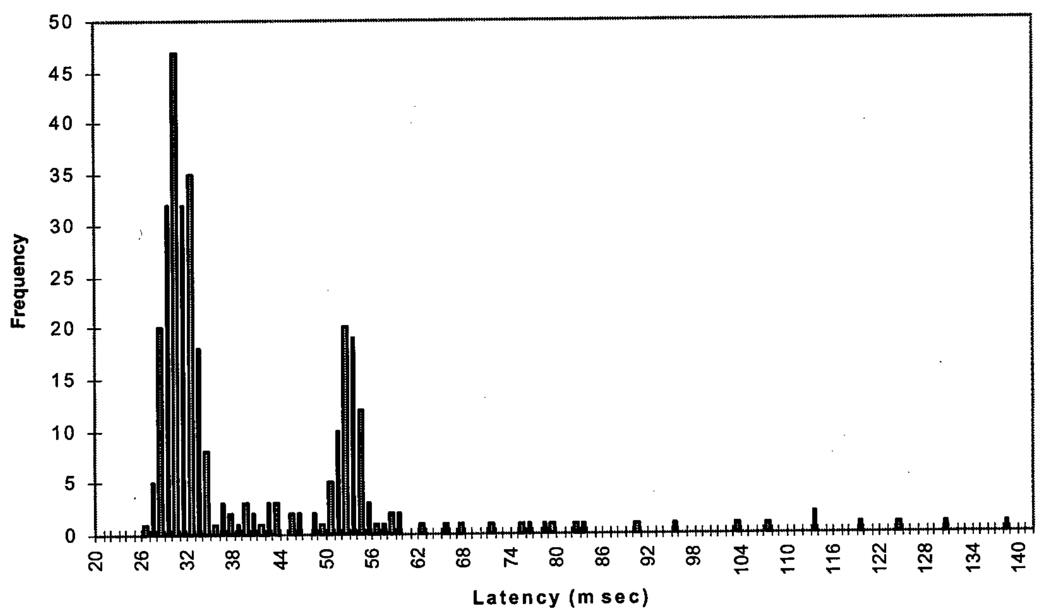


Figure 4.3.3.1-18b. Frequency Histogram of Latency of Shooter Entity State Data (before launch) Between WSSF Simulation and WSIC PDU Logger (Run #12 on 11/19/96)

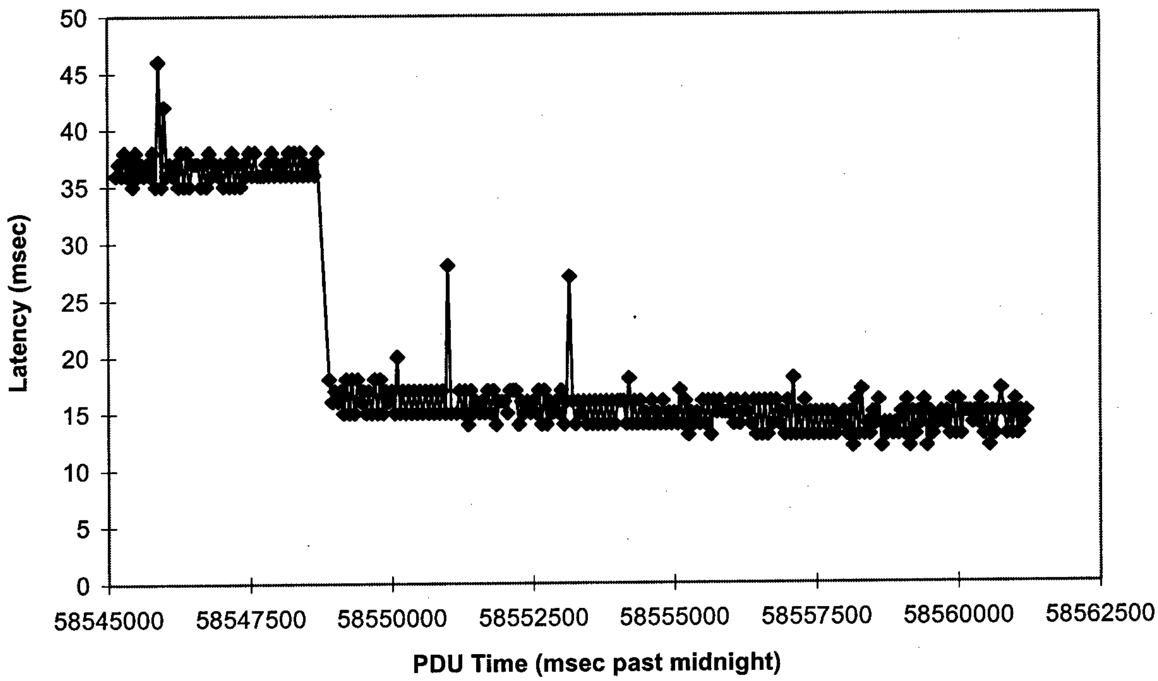


Figure 4.3.3.1-19. Latency of Shooter Entity State Data (before launch) Between WSSF Simulation and WSSF PDU Logger (Run #12 on 11/19/96)

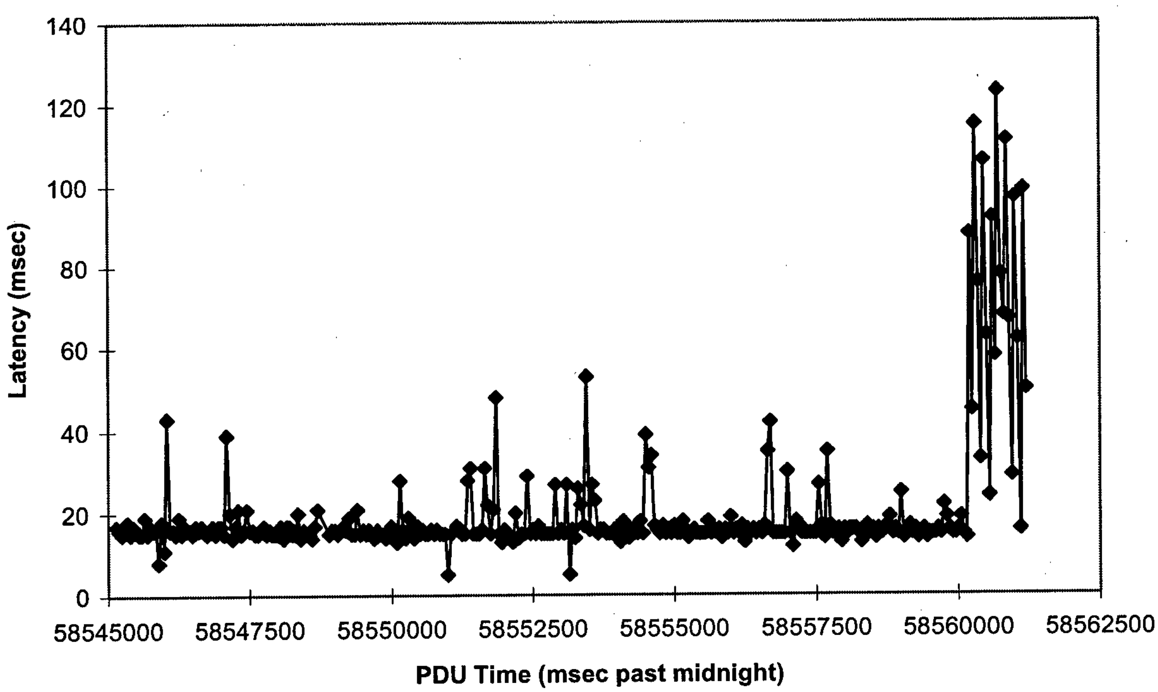


Figure 4.3.3.1-20. Latency of Shooter Entity State Data (before launch) Between WSSF PDU Logger and WSIC PDU Logger (Run #12 on 11/19/96)

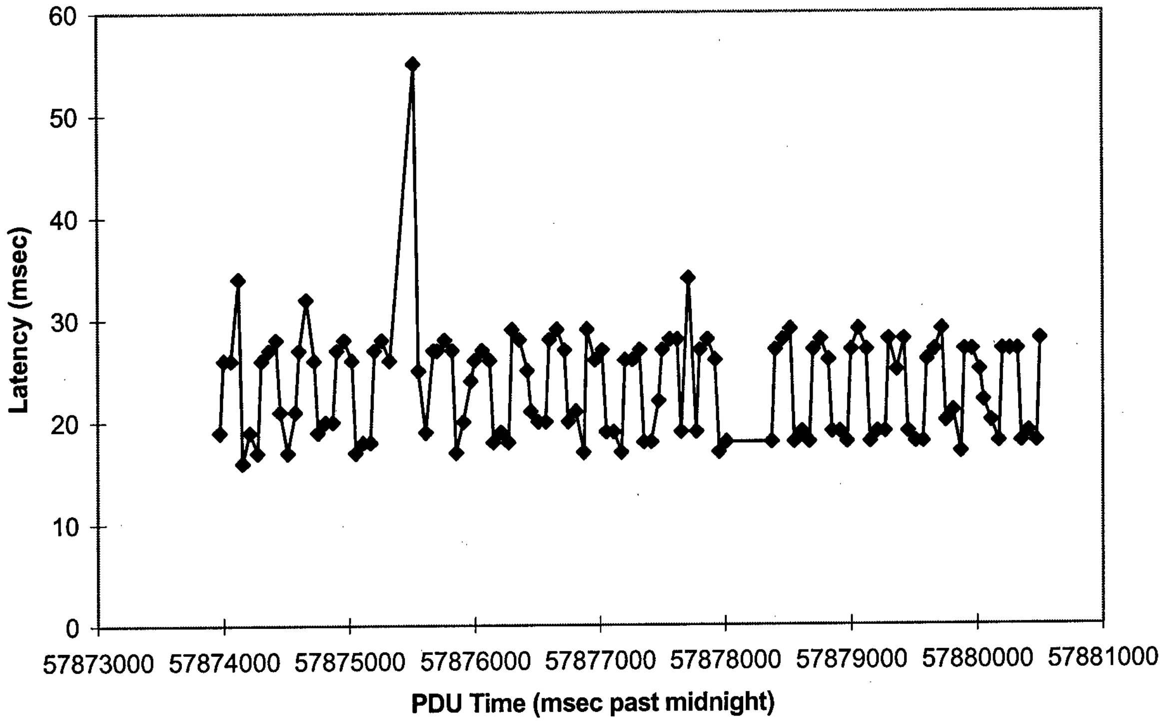


Figure 4.3.3.1-21a. Latency of Target Entity State Data (after launch) Between WSIC Simulation and SIMLAB PDU Logger (Run #9 on 11/19/96)

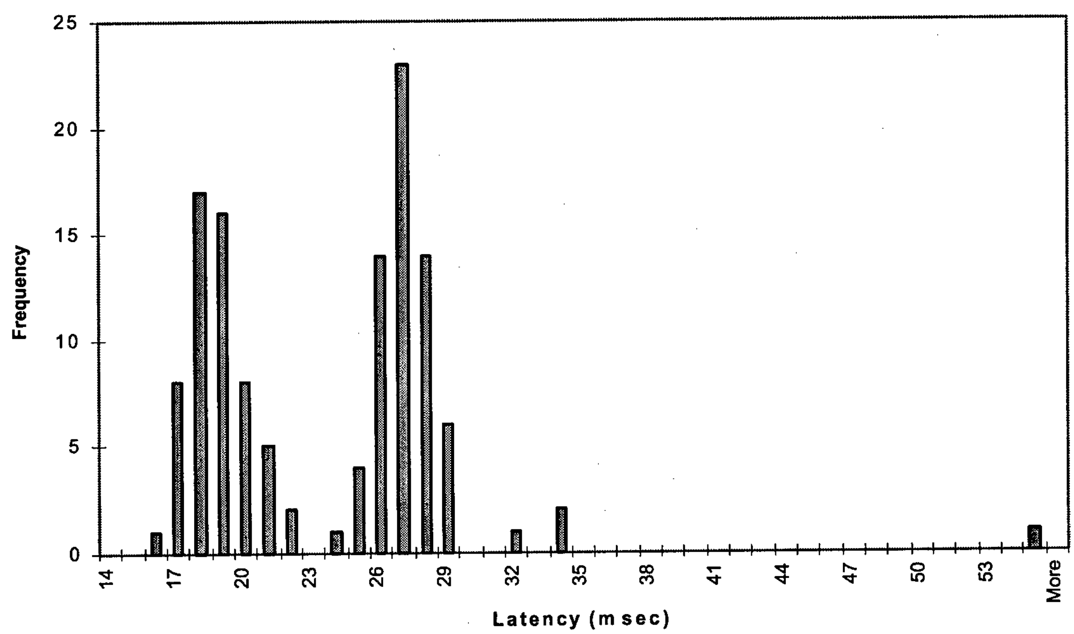


Figure 4.3.3.1-21b. Frequency Histogram of Latency of Target Entity State Data (after launch) Between WSIC Simulation and SIMLAB PDU Logger (Run #9 on 11/19/96)

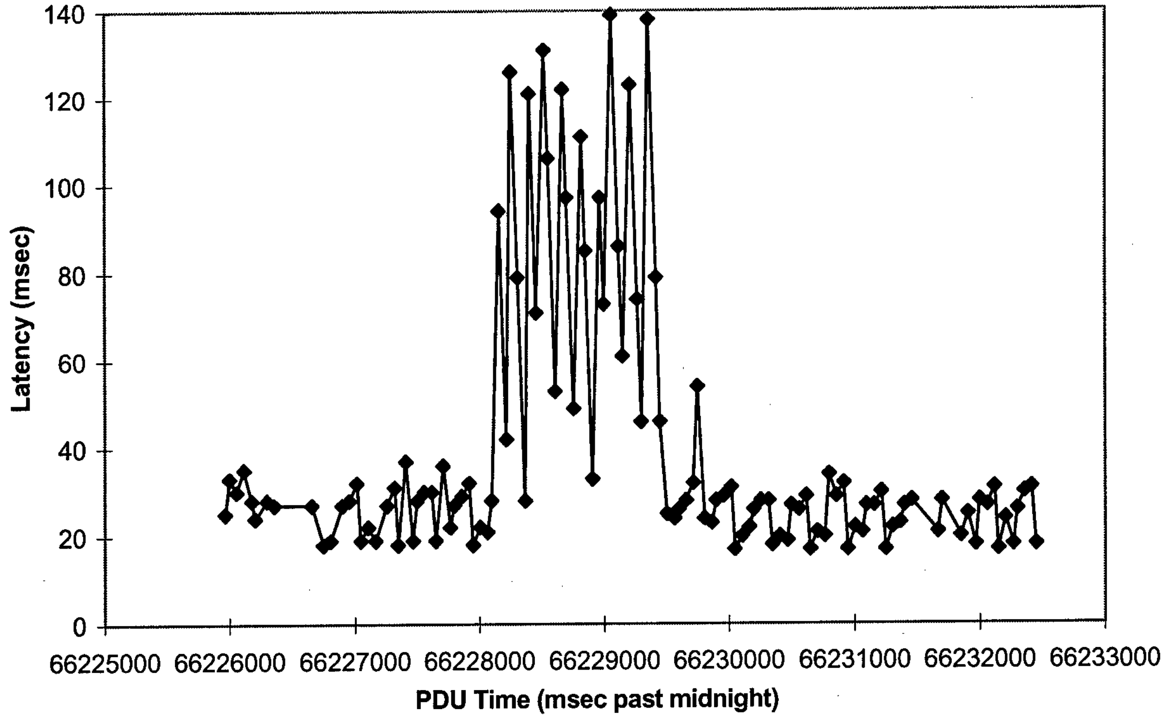


Figure 4.3.3.1-22a. Latency of Target Entity State Data (after launch) Between WSIC Simulation and SIMLAB PDU Logger (Run #19 on 11/19/96)

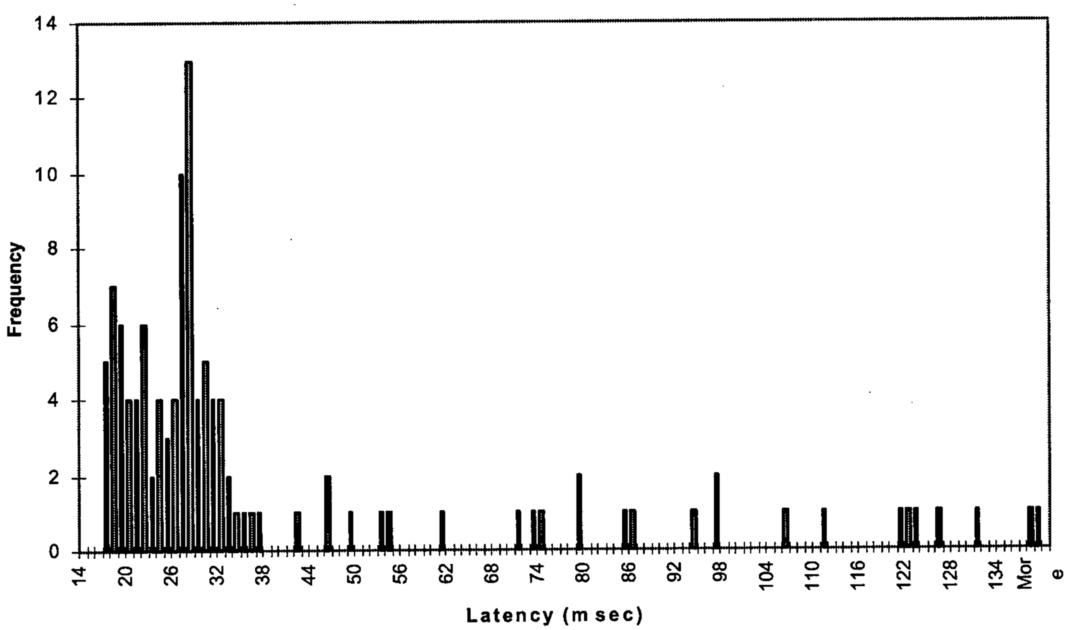


Figure 4.3.3.1-22b. Frequency Histogram of Latency of Target Entity State Data (after launch) Between WSIC Simulation and SIMLAB PDU Logger (Run #19 on 11/19/96)

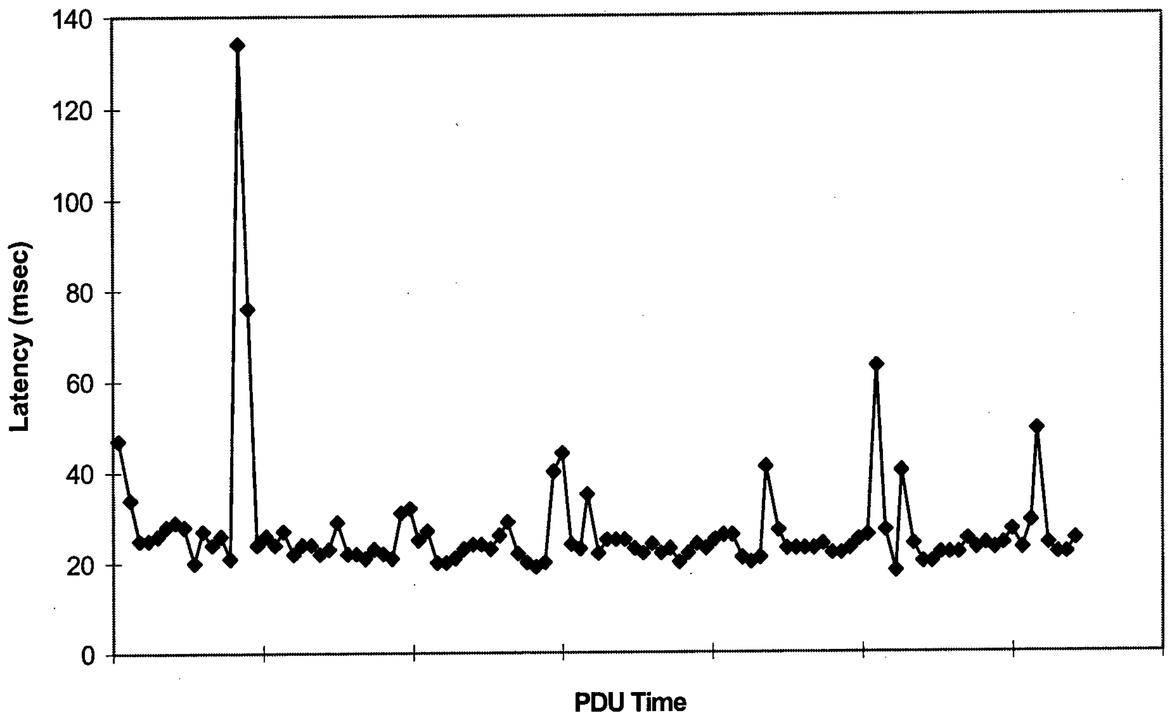


Figure 4.3.3.1-23a. Latency of Missile Entity State Data Between SIMLAB Simulation and WSIC PDU Logger (Run #9 on 11/19/96)

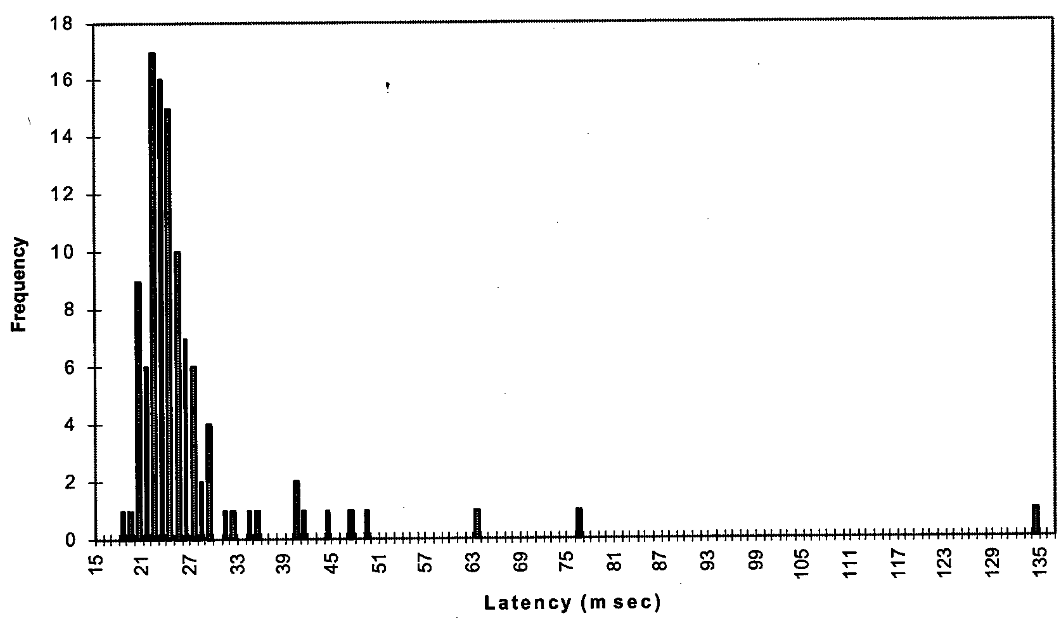


Figure 4.3.3.1-23b. Frequency Histogram of Latency of Missile Entity State Data Between SIMLAB Simulation and WSIC PDU Logger (Run #9 on 11/19/96)

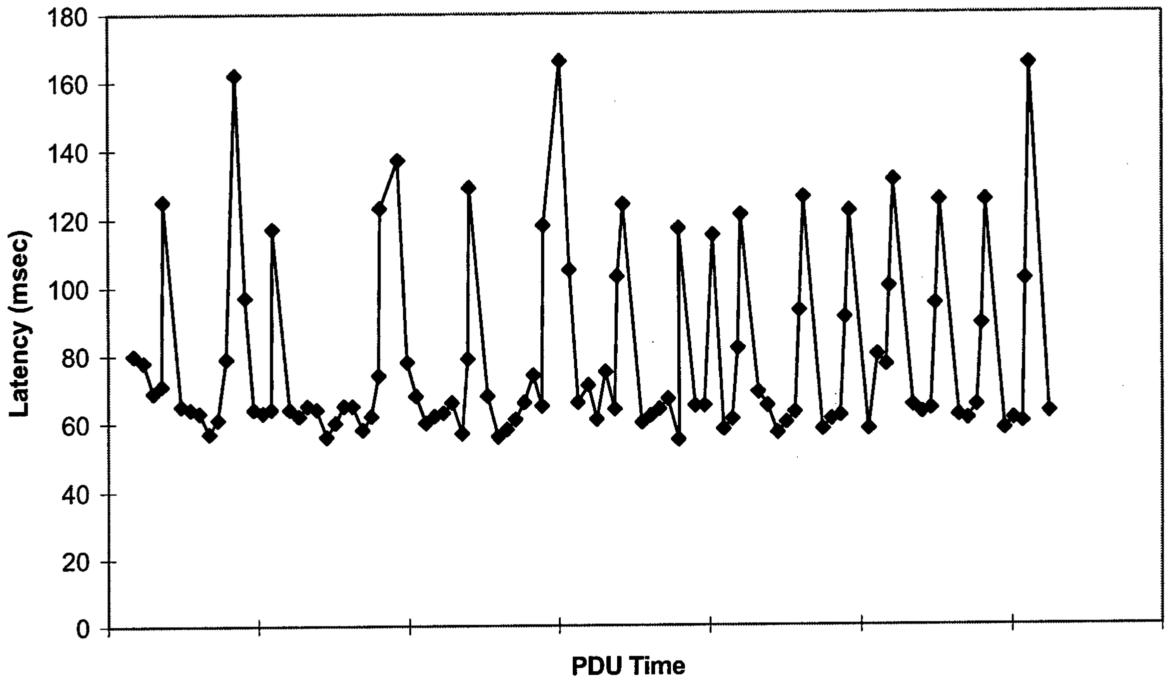


Figure 4.3.3.1-24a. Latency of Missile Entity State Data Between SIMLAB Simulation and WSIC PDU Logger (Run #12 on 11/19/96)

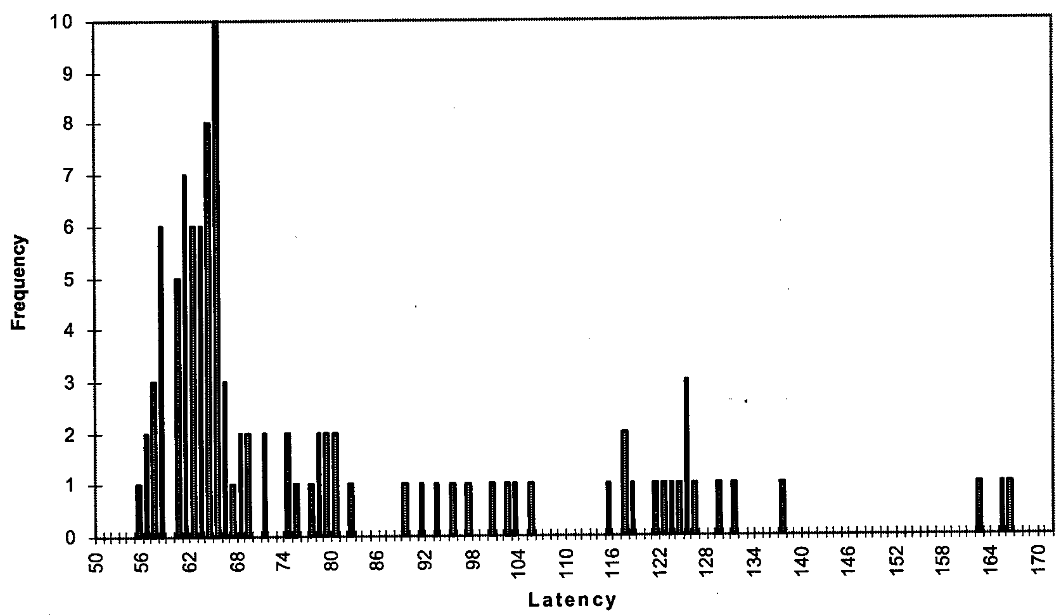


Figure 4.3.3.1-24b. Frequency Histogram of Latency of Missile Entity State Data Between SIMLAB Simulation and WSIC PDU Logger (Run #12 on 11/19/96)

The following is noted from Tables 4.3.3.1-8 through 4.3.3.1-13 and Figures 4.3.3.1-11 through 4.3.3.1-24:

- Target Entity State Data Latencies (before launch)
  - -- The mean latencies of the target entity state data were very small and consistent run-to-run (Table 4.3.3.1-8). The mean latencies between the WSIC simulation and the WSIC PDU logger were ~50% of the values from the V&V Mission. The mean latencies between the WSIC PDU logger and the WSSF PDU logger were essentially the same as for the V&V Mission.
  - -- As Table 4.3.3.1-8 shows, the mean latency between the WSIC simulation and the WSIC PDU logger was about half of the mean transmission latency between PDU loggers.
  - -- As Figure 4.3.3.1-11 shows, there was grouping of the target entity state PDUs into two groups. This is shown most clearly in the latency frequency histogram (Fig. 4.3.3.1-11b).
  - -- Comparing Figures 4.3.3.1-12 and 4.3.3.1-13 to Figure 4.3.3.1-11a shows that the grouping was a characteristic of the WSIC simulation/WSIC NIU output. Figure 4.3.3.1-12 shows that the target PDUs logged at the WSIC either had a latency of ~5 msec or ~15 msec. On the other hand, the latency between the WSIC PDU logger and the WSSF PDU logger displayed a single group centered about the mean latency (18 msec).
  - -- Figure 4.3.3.1-14 shows the target entity state data latency on a run in which some uncharacteristically large latency values appeared over a relatively short duration. The latency frequency histogram (Fig. 4.3.3.1-14b) shows that there were two primary latency groups, as before, along with several high latency "spikes" (latencies significantly exceeding the mean-plus-one-standard-deviation value).
  - -- Comparing Figures 4. 3.3.1-15 and 4.3.3.1-16 to Figure 4.3.3.1-14a shows that the latency "spikes" were associated with the latency between the WSIC and the WSSF PDU loggers. In other words, the latency between nodes was not always well behaved.
    - --- Some of the latency "spikes" may have been due to delays in logging the PDUs in the WSSF PDU logger, rather than variations in the transmission latency. By comparing PDU data logged by the SNAP loggers with that logged by the DIS (STRICOM) loggers, it was determined that delays of tens of msec could occur in logging the PDUs at the DIS PDU loggers (copies of the PDU data were buffered at the loggers before the data were time stamped and recorded; this did not delay transmission of the PDUs). However, on average the DIS PDU logger agreed with the SNAP loggers to within one msec, the resolution of the PDU creation and logging time stamps (all logger latencies reported in this section are for data logged on the DIS loggers).
  - -- The latency of the target entity state data from the W SSF PDU logger into the WSSF simulation were determined by matching data in the target PDUs with data logged in the WSSF simulation. The results are given in Table 4.3.3.1-12.
    - --- The entity state data used for the match were the east velocity components of the target. The north or east velocity components usually gave a clear match between

PDU data and simulation data, whereas positional data did not. The reason was that the positional data were dead reckoned by the WSSF NIU between PDU updates, whereas the velocity data were not.

--- Comparing Table 4.3.3.1-12 with Table 4.3.3.1-8 shows that the mean latency of the target data between the WSSF PDU logger and the WSSF simulation was about four times that between the WSIC simulation and the WSIC PDU logger. Note that a number of latency determinations gave negative values (most likely due to time stamping errors), so that the latencies given in Table 4.3.3.1-12 are suspected of being too low.

--- The total mean latency between the WSIC simulation and t he WSSF simulation shows that the WSSF simulation was usually running one PDU update time (50 msec) behind the WSIC simulation on five of the runs and within one PDU update time of the WSIC simulation on one of the runs. However, there were instances during a run in which an individual frame of the WSSF simulation was as many as seven PDU update times (350 msec) behind the WSIC simulation.

-- The maximum values of latency between the WSSF logger and the WSSF simulation resulted when an updated target PDU was not received by the WSSF NIU by the time data was to be logged by the WSSF simulation (every 50 msec). When this occurred, the NIU dead reckoned the positional data from the last PDU for the input into the WSSF simulation. However, the PDU velocity data were not dead reckoned. The result was that the target positional data changed relatively smoothly when the PDUs were not being updated regularly, but the velocity data did not. This is an example of an ADS-induced error and will be evaluated under Test Objective 4-2.

- <u>Shooter Entity State Data Latencies (before launch)</u>

-- The mean latencies of the shooter entity state data were small and consistent run-to-run (Table 4.3.3.1-9). The mean latencies between the WSSF simulation and the WSSF PDU logger were about the same as those for the lowest mean latency run from the V&V Mission and did not show the progressive growth seen in the V&V Mission. The mean latencies between the WSSF PDU logger and the WSIC PDU logger were essentially the same as for the V&V Mission.

-- As Table 4.3.3.1-9 shows, the mean latency between the WSSF simulation and the WSSF PDU logger was more than twice the mean transmission latency between PDU loggers.

-- As Figure 4.3.3.1-17 shows, the latencies primarily fell into a single group. However, there were a number of lower and higher latency "spikes" falling outside the group.

-- Table 4.3.3.1-9 shows that Run #12 had an unusually low mean latency. Figure 4.3.3.1-18 shows that the latency on this run began lower than the mean values on other runs and then shifted to an even lower value. This shift resulted in the latencies being primarily in two groups for this run (Fig. 4.3.3.1-18b).

-- Figure 4.3.3.1-18a also shows that the latencies on Run #12 exhibited "spiking" just before missile launch. Comparing Figures 4.3.3.1-19 and 4.3.3.1-20 to Figure 4.3.3.1-18a shows that the "spiking" was associated with the latency between the WSSF and

WSIC PDU loggers. Again, here is an example of the latency between nodes not being well behaved.

-- The mean latency of the shooter entity state data from the WSIC PDU logger into the WSIC simulation was checked and found to be relatively large (~100 msec). The shooter data were not used by the WSIC simulation; they were only logged there. These latency values do not necessarily represent the latency of inputting the shooter data into the WSIC simulation.

- <u>Target Entity State Data Latencies (after launch)</u>
  -- The mean latencies of the target entity state data after launch (Table 4.3.3.1-10) were essentially the same as before the launch (Table 4.3.3.1-8). The mean latencies between the WSIC PDU logger and the SIMLAB PDU logger were within 2 msec of those between the WSIC PDU logger and the WSSF PDU logger.
  -- As Figure 4.3.3.1-21 shows, the grouping of the target entity state PDUs into two groups continued after missile launch. This is shown most clearly in the latency frequency histogram (Fig. 4.3.3.1-21b). Note the high latency "spike."
  -- Figure 4.3.3.1-22 shows that the target entity st ate data exhibited a burst of high latency "spikes" on Run #19, much like the burst before launch (Fig. 4.3.3.1-14). As Table 4.3.3.1-10 shows, this burst was associated with the latency between the WSIC and the SIMLAB PDU loggers, rather than the latency between the WSIC simulation and the WSIC PDU logger.
  -- The latency of the target entity state data from the SIMLAB PDU logger into the SIMLAB simulation were determined by matching the north velocity components of the target in the PDU data with the corresponding data logged in the SIMLAB simulation. The results are given in Table 4.3.3.1-13. Comparing Table 4.3.3.1-13 with Table 4.3.3.1-10 shows that the latency of the target data between the SIMLAB PDU logger and the SIMLAB simulation was more than four times that between the WSIC simulation and the WSIC PDU logger. The total latency between the WSIC simulation and the SIMLAB simulation shows that the SIMLAB simulation was usually running about one PDU update time (50 msec) behind the WSIC simulation. However, there were instances during a run in which an individual frame of the SIMLAB simulation was as many as seven PDU update times (350 msec) behind the WSIC simulation.
    --- Comparing Table 4.3.3.1-13 with Table 4.3.3.1-12 shows that the total latency of the target data between the WSIC simulation and the SIMLAB simulation was about the same as that between the WSIC simulation and the WSSF simulation, about 70 msec. As noted previously, most of this latency was between the NIU at the receiving node and the simulation at that node.
    --- When the target's north velocity component was matched, it was noted that the target velocity was not being updated in the SIMLAB simulation at the same rate as the target positional data. This resulted when an updated target PDU was not received by the SIMLAB NIU by the time data was to be logged by the SIMLAB simulation, just as noted above for the target data received by the WSSF. As a result, the target velocity data were occasionally updated at a low rate (as low as

~3 Hz). This was an example of an ADS-induced error and was evaluated under Test Objective 4-2 (Section 4.4.2.3).

- Missile Entity State Data Latencies
  - -- The mean latencies of the missile entity state data were small and consistent run-to-run (Table 4.3.3.1-11), with the exception of Run #12. The mean latencies between the SIMLAB simulation and the SIMLAB PDU logger were about the same as those for the lowest latency run from the V&V Mission. The mean latencies between the SIMLAB PDU logger and the WSIC PDU logger were essentially the same as for the V&V Mission.
  - -- As Table 4.3.3.1-11 shows, if Run #12 is excluded, the mean latency between the SIMLAB simulation and the SIMLAB PDU logger was less than half of the mean transmission latency between PDU loggers and was about the same as the mean latency of the target entity state data between the WSIC simulation and the WSIC PDU logger.
  - -- As Figure 4.3.3.1-23 shows, the latencies primarily fell into a single group. However, there were a number of higher latency "spikes" falling outside the group.
  - -- Table 4.3.3.1-11 shows that Run #12 had an unusually high mean latency. Figure 4.3.3.1-24 shows that the latency on this run had a higher baseline and a larger number of high latency "spikes" compared to Run #9 (Fig. 4.3.3.1-23). Note that the "spikes" on Run #12 were distributed throughout the missile flyout.
  - -- The mean latency of the missile entity state data between the WSIC PDU logger and the WSIC simulation was checked and found to be about 50% larger than the mean latency of the target entity state data between the SIMLAB PDU logger and the SIMLAB simulation (63 msec vs. 45 msec). The missile data were not used by the WSIC simulation; they were only logged there. These latency values do not necessarily represent the latency of inputting the missile data into the WSIC simulation.

SUMMARY. The mean latencies of all entity state data were relatively small and consistent run-to-run. The mean transmission latencies between the simulation nodes were essentially the same as for the V&V Mission, about 20 msec for all the node pairs. The mean latency of the target and missile entity state data between their creating simulations and the first PDU logger was generally less than half of the mean transmission latency between nodes. However, the mean latency of the shooter entity state data between the WSSF simulation and the WSSF PDU logger was more than twice the mean transmission latency. The mean latencies of the target and missile entity state data between the PDU logger and simulation at the receiving node were more than twice the mean latencies between the simulation and the PDU logger at the creating node. The mean latencies between any pair of nodes still exhibited relatively large sample-to-sample variations, and high latency "spikes" were still observed, even between the PDU loggers. However, some of the "spikes" may have been caused by delays in time stamping the PDU data at the loggers.

4.3.3.2 Latency Effects

4.3.3.2.1 Entity Presentation Errors

As noted in Sections 4.1.1.2 and 4.1.1.3, the random variations in latency between the WSIC and the SIMLAB during a run resulted in an uncertainty in the target location, as perceived at the SIMLAB. This complicated the dynamic verification of the target presentation in the SIMLAB and prevents the implementation of a deterministic real-time correction for latency effects. Table 4.1.1.3-3 gives the results of applying Equation 1 to the latency characteristics of the Parametric Study Mission runs and shows that the average of the mean uncertainties of the target position for the six complete V2 runs was about 32 ft. This is significantly larger than the lethal radius of the missile, so that lethality results from the LSP configuration cannot be considered valid. Also, note that the uncertainty value quoted is based on the standard deviation of the latency. Some of the high latency "spikes" were up to ten times the standard deviation, so that the observed target position might instantaneously diverge from its correct location by over 300 ft.

Some of the large latency values caused uncharacteristically large time intervals between target entity state updates at the receiving nodes. The normal time between creating target PDUs at the WSIC was about 50 msec, but occasionally large latencies would prevent the target PDUs from being updated at the receiving nodes for several hundred milliseconds. When such large time gaps between updates occurred, the target velocity data input into either the WSSF or the SIMLAB simulation would not be updated during the gap (however, the target position was "updated" during the gap by dead reckoning, so that the target position and velocity were inconsistent with each other during the gap). When the next updated target PDU was received, a discontinuous adjustment of the target velocity would occur.

- The impact of this on the WSSF was that the closing velocity between the shooter and target, v_c, was observed by the shooter pilot to "jump" at times.
- The impact of this on the SIMLAB simulation was aggravation of the latitude divergence problem (see Section 4.1.1.3), since the SIMLAB simulation integrated the target velocity to determine the target position.

Large gaps in updating the PDU data at the receiving nodes were also caused by irregularities in the PDU creation rate (see Section 4.4.2.3).

Random latency variations were also evident in the data for the other entities. Hence, the shooter and the missile positions perceived at other nodes were likewise uncertain, and their velocities exhibited discontinuities. Since the missile had a much higher velocity than the target (~3 times larger), the uncertainty in its position, as perceived by the target, was proportionately larger.

Besides discontinuities in entity presentation, the high latency "spikes" can affect the overall simulation performance, if they occur during critical functions. This may have caused the SIMLAB Carco table to exceed its gimbal limits on some of the runs (because the target presentation exceeded the allowable seeker field-of-view). When this happened, the missile simulation was immediately terminated before the missile could complete its simulated flyout.

4.3.3.2.2 Launch Conditions Differences Between Nodes

The launch conditions were determined from data collected at the various logging locations and using the procedures discussed in Section 4.3.2. The Time of Flare Release and the Time of Evasive Maneuver were not determined, because these applied to scenarios from the planned Latency Study Mission which were not executed. Results are expressed as differences in the launch condition parameters as determined for the various nodes.

V&V Mission

SIMLAB Simulation Data Compared to SIMLAB Logged PDU Data . The differences between the launch conditions from the PDUs logged at the SIMLAB and those from the SIMLAB simulation were computed and are given in Table 4.3.3.2.2-1. The launch conditions as logged from the SIMLAB simulation were generally accepted as the set of launch conditions for each run and were the source of data for Test Objective 2. Note that three relative latencies are given (these are differences in latencies of data logged at PDU logger and data logged in simulation): the latency of the Fire (Missile) PDUs logged at the SIMLAB PDU logger (reflecting latency between the SIMLAB simulation and the SIMLAB PDU logger), the relative latency of the shooter entity state data, and the relative latency of the target entity state data. Differences are not given for shooter velocity, target velocity, and target altitude; these differences were always minimal, because of the nature of the LPN-15 scenario.

Table 4.3.3.2.2-1. Differences Between Launch Conditions from PDUs Logged at SIMLAB and Launch Conditions from SIMLAB Simulation (10/29/96)

					Relative Latencies (ms)		
Run #	Range (ft)	Sh Alt (ft)	Aspect (°)	Lead (°)	FIRE	Shooter	Target
3	-86.6	-9.8	0.87	0.04	90	-35	-55
4	-89.3	-9.3	0.65	-0.29	109	-31	-22
5	-170.7	-18.2	1.52	0.32	253	-18	-27
7	-208.8	-16.7	2.08	-1.39	412	-8	-31
8	-274.5	-21.5	2.29	-1.25	463	51	-25
10	-68.0	-1.9	0.22	0.07	35	-23	0
15	-61.1	-2.6	0.22	0.07	33	23	-7
16	-38.2	-2.4	0.52	-0.22	33	14	-33
18	-255.9	-65.1	3.23	-1.92	676	20	-52
19	154.5	-2.5	2.40	-1.50	441	473	15
20	-241.3	-46.1	2.37	-1.45	471	-44	-28
23	-330.3	-74.1	4.61	-1.39	822	7	-37
25	-246.0	-66.5	4.71	1.17	570	109	-78
26	-258.5	-47.9	3.27	-1.88	579	44	-8

The following is noted from Table 4.3.3.2.2-1:

- The differences between the launch conditions determined from the PDUs and those from the SIMLAB simulation generally increased as the latency of the Fire (Missile) PDU increased. This relationship was generally true because the latency of the Fire (Missile) PDU usually dominated the relative latencies of the shooter and target entity state data.
- In general, the launch range from the PDU data was smaller than that from the simulation data. This occurred because the shooter was closing on the target, and the PDU data used to determine the launch conditions corresponded to a later time than for the simulation data (the launch conditions were determined from the logged PDU data when the Fire (Missile) PDU which was generated in the simulation was received by the PDU logger).
- The shooter altitude from the PDU data was lower than that from the simulation data because the shooter was losing altitude with time, and the PDU data corresponded to a later time.
- The target aspect angle from the PDU data was larger than that from the simulation data because the turning of the target caused the aspect angle to increase with time, and the PDU data corresponded to a later time.
- The lead angle depended on how the shooter was maneuvering prior to the launch. This varied slightly from run-to-run, so that a clear trend in the lead angle was not obvious.
- The exception to the trend of the launch range differences increasing with Fire (Missile) PDU latency was Run #19. On this run the shooter entity state data had a much larger latency at the PDU logger than into the SIMLAB simulation (the simulation and the logger used the same set of shooter entity state data because update time of the logged shooter entity state PDUs was abnormally long), while the target entity state data had about the same latency. In this case, the shooter data from PDUs represented a much earlier position relative to the target, so that the launch range from the PDU data was longer than that from the SIMLAB simulation.
- The launch range differences in Table 4.3.3.2.2-1 are plotted versus the Fire (Missile) PDU latency in Figure 4.3.3.2.2-1, excluding the data for Run #19. This figure illustrates the general trend noted above. Note that the linear fit to the data in the figure does not pass through the origin (i.e., zero Fire (Missile) PDU latency did not correspond to a zero launch range difference). This was because the launch range differences were also due to the shooter and target entity state data latencies (i.e., if the Fire (Missile) PDU latency was reduced to zero there would still be latencies in the shooter and target data). Figure 4.3.3.2.2-1 shows that Fire (Missile) PDU latencies need to be less than 100 msec if the differences in launch range are to be less than 100 ft.

<u>SIMLAB Simulation Data Compared to WSSF Simulation Data</u>. The differences between the launch conditions from the SIMLAB simulation and those from the WSSF simulation were computed and are given in Table 4.3.3.2.2-2. The launch conditions from the SIMLAB simulation were logged for each run. However, the launch conditions for the WSSF were not computed by the simulation and had to be determined after the test as follows:

- The launch event at the WSSF was determined by using the shooter altitude from the F/A-18 cockpit data display which appeared at trigger squeeze.
  - -- The shooter simulation data frame logged at the WSSF which had the same shooter altitude was located, and other shooter parameters were noted.

-- The target simulation data frame logged at the WSSF with the same IRIG time as the shooter frame was located, and the target parameters were noted.
- The launch conditions were computed from the shooter and target data.

For this comparison, the differences were found to relate primarily to the latency of the shooter entity state data received at the SIMLAB relative to the latency of the launch indication received at the SIMLAB from the WSSF. The entries for relative SIMLAB latencies in Table 4.3.3.2.2-2 are the differences between the latency of the shooter entity state data received at the SIMLAB and the latency of the SIMLAB launch indication (i.e., differences of the two previous columns).

Table 4.3.3.2.2-2. Differences Between Launch Conditions from SIMLAB Simulation and Launch Conditions from WSSF Simulation (10/29/96)

					SIMLAB Latencies (ms)		
Run #	Range (ft)	Sh Alt (ft)	Aspect (°)	Lead (°)	Launch	Shooter	Relative
3	155.2	5.5	1.32	-1.09	-33	67	100
4	160.8	4.5	2.12	-0.94	-18	83	101
5	163.5	4.6	1.91	-1.64	-20	80	100
7	161.1	2.0	1.01	-1.08	2	55	53
8	305.5	15.8	0.1	-0.52	-25	328	353
10	343.8	9.2	0.1	-0.71	6	453	447
15	557.3	46.1	0.82	-0.46	-21	679	700
16	491.1	42.8	0.24	-0.17	-30	621	651
18	550.9	69.9	0.32	-0.56	-7	745	752
19	519.0	47.9	0.51	-0.53	8	602	594
20	562.8	61.5	0.11	-0.47	11	759	748
23	582.4	63.9	-0.31	-1.19	-9	743	752
25	679.6	82.1	-1.17	-3.50	-356	693	1049
26	544.6	53.9	0.53	-0.41	15	716	701

The following is noted from Table 4.3.3.2.2-2:

- The latencies of the launch indication received at the SIMLAB were much smaller than the latencies of the shooter entity state data. Also, the latencies of the launch indication were about the same run-to-run, with the exception of Run #25. This occurred because the launch indication was sent from the WSSF to the SIMLAB over a dedicated link as part of the pre-launch SMS data, so that it did not share the link with the entity state data. In other words, the SMS data was significantly out of synchronization with the shooter entity state data. Since the launch signal was generated at the WSSF, the negative latencies to the SIMLAB do not make physical sense and probably indicate a timing problem.
- Because the launch indication latency was much smaller than the shooter entity state data, the SIMLAB utilized relatively older shooter entity state data at time of launch, when the shooter was at a larger range from the target and at a higher altitude. This is reflected in

the positive differences in the launch ranges and shooter altitudes determined by the SIMLAB as compared to these parameters determined by the WSSF.

- The target aspect angle determined by the SIMLAB w as generally larger than that determined by the WSSF because the latency of the target data into the SIMLAB simulation was usually significantly less than that into the WSSF simulation. As a result, the SIMLAB perceived a more recent target bearing. Since the turning of the target caused the aspect angle to increase with time, the SIMLAB determined a larger angle.
- The launch range differences in Table 4.3.3.2.2-2 are plotted versus the latency of the SIMLAB launch indication relative to the latency of the shooter entity state data in Figure 4.3.3.2.2-2. This figure illustrates the trend noted above. Note that the linear fit to the data in the figure again does not pass through the origin (as for Fig. 4.3.3.2.2-1). Figure 4.3.3.2.2-2 shows that other latencies (primarily the latency of the target entity state data to the WSSF simulation) prevented achieving launch range differences of less than 100 ft.

WSIC Logged PDU Data Compared to WSSF Simulation Data . The differences between the launch conditions from the PDUs logged at the WSIC and those from the WSSF simulation were computed and are given in Table 4.3.3.2.2-3. This comparison helped to quantify the effects of latency between the shooter and the target simulations. Unfortunately, shooter entity state data were not logged in the WSIC simulation during the V&V Mission, so that a direct comparison between the WSIC and WSSF simulations was not possible. As in Table 4.3.3.2.2-2, the differences were found to relate primarily to the latency of the shooter entity state data logged at the WSIC relative to the latency of the Fire (Missile) PDUs logged at the WSIC. The entries for relative WSIC latencies in Table 4.3.3.2.2-3 are the differences between the latency of the shooter entity state data logged on the WSIC PDU logger and the latency of the Fire (Missile) PDUs logged on the WSIC PDU logger (i.e., differences of the two previous columns).

Table 4.3.3.2.2-3. Differences Between Launch Conditions from PDUs Logged at WSIC and Launch Conditions from WSSF Simulation (10/29/96)

					WSIC Latencies (ms)		
Run #	Range (ft)	Sh Alt (ft)	Aspect (°)	Lead (°)	FIRE	Shooter	Relative
3	67.1	-5.1	2.27	-1.09	107	67	-40
4	82.7	-5.7	3.02	-1.39	125	83	-42
5	-0.5	-14.1	3.65	-1.48	272	80	-192
7	-45.1	-15.0	3.21	-2.59	435	59	-376
8	29.3	-6.2	2.54	-1.88	482	386	-96
10	281	7.2	0.44	-0.74	51	453	402
15	498	43	1.13	-0.43	49	710	661
16	456.3	39.9	0.91	-0.49	51	641	590
18	303.6	4.7	3.67	-2.57	689	776	87
19	696.2	45.3	3.19	-2.11	464	1151	687
20	328.5	15.4	2.58	-1.99	560	804	244
23	236.9	-21.6	5.33	-2.97	937	743	-194
25	441.7	14.9	3.70	-2.44	587	809	222

26	294.8	6.0	3.93	-2.38	596	754	158

The following is noted from Table 4.3.3.2.2-3:

- The latencies of the Fire (Missile) PDUs received at the WSIC were sometimes smaller and sometimes larger than the latencies of the shooter entity state data.
  - -- The signs of the shooter altitude difference agreed with the signs of the relative latencies, as would be expected (positive relative latency corresponds to older shooter entity state data when the shooter was at a higher altitude and vice versa).
  - -- In those cases in which the relative latency was positive, positive launch range differences resulted, as in Table 4.3.3.2.2-2. However, negative relative latencies resulted in either positive or negative launch range differences; other latencies appeared to be a factor here.
  - -- The differences in target aspect angle appeared to be related to the Fire (Missile) PDU latency itself, as in Table 4.3.3.2.2-1. Note that Fire (Missile) PDU latencies must be less than about 50 msec if the differences in aspect angle are to be less than 1°.
- The launch range differences in Table 4.3.3.2.2-3 are plotted versus the latency of the shooter entity state data relative to the latency of the WSIC Fire (Missile) PDU in Figure 4.3.3.2.2-3. This figure also contains the launch range differences plotted in Figure 4.3.3.2.2-2 and illustrates the general trend noted above. Note that the linear fit to the data in the figure again does not pass through the origin (as for Figs. 4.3.3.2.2-1 and 4.3.3.2.2-2) and parallels the linear fit from Figure 4.3.3.2.2-2. Figure 4.3.3.2.2-3 shows that negative relative latencies (Fire (Missile) PDU latency greater than shooter PDU latency) with magnitudes greater than 100 msec are needed if the differences in launch range are to be less than 100 ft. In other words, the Fire (Missile) PDU latency would have to be greater than 100 msec to achieve launch range differences less than 100 ft. This is not consistent with the conclusion above that Fire (Missile) PDU latencies must be less than 50 msec for the differences in the target aspect angle to be less than 1 °. This inconsistency is due to the target entity state data latencies not being considered. The implication here is that the latencies for all entity state data and for the Fire (Missile) PDU must be less than about 50-100 msec to achieve good agreement between the shooter and target on all launch conditions (launch range within 100 ft, shooter altitude within 10 ft, and target aspect angle and lead angle within 1°).

WSIC Logged PDU Data Compared to WSSF Logged PDU Data. The differences between the launch conditions from the WSIC PDU data and those from the WSSF PDU data were computed and are given in Table 4.3.3.2.2-4. This table shows how well the PDU data logged at various locations agreed, because this particular comparison resulted in the largest differences for any pair of PDU loggers. Relative latencies are given in the table, as in Table 4.3.3.2.2-1.

Table 4.3.3.2.2-4 shows excellent agreement for all launch conditions. This was due to the small latencies (mean values of ~20 msec) between the PDU loggers during the V&V Mission. The small logger-to-logger latencies resulted in small relative latencies in Table 4.3.3.2.2-4. This table reinforces the conclusion that latencies less than about 50-100 msec were required for good agreement between the shooter and target on all launch conditions.

Table 4.3.3.2.2-4. Differences Between Launch Conditions from PDUs Logged at WSIC and Launch Conditions from PDUs Logged at WSSF (10/29/96)

					Relative Latencies (ms)		
Run #	Range (ft)	Sh Alt (ft)	Aspect (°)	Lead (°)	FIRE	Shooter	Target
3	8.8	0.3	0.06	-0.07	6	11	-13
4	22.4	0.6	0.21	-0.15	6	15	-28
5	18.4	0.7	0.19	-0.13	10	19	-21
7	15.0	0.2	0.11	-0.09	16	23	-18
8	11.7	0.4	0.12	-0.10	7	15	-13
10	18.0	0.2	0.09	-0.10	5	19	-13
15	76.2	7.0	0.01	-0.09	-22	78	-24
16	15.5	0.7	0.10	-0.10	6	16	-9
18	12.8	0.5	0.10	-0.07	6	12	-11
19	26.6	0.7	0.24	-0.16	15	24	-23
20	5.3	0.03	0.07	-0.05	79	79	56
23	13.8	1.0	0.06	-0.05	17	17	-12
25	17.4	0.9	0.10	-0.07	17	17	-16
26	6.9	0	0.10	-0.07	6	6	-11
Mean	19.2	0.9	0.11	-0.09	10.9	25.1	-11.1
Std Dev	17.4	1.8	0.06	0.03	21.5	23.1	23.1

CONCLUSION. Large latencies (>100 msec) result in significant differences between the launch conditions determined at the various nodes. Significant differences were observed between the launch conditions determined by the SIMLAB simulation as compared to the WSSF simulation. These differences were due to the relatively large latencies between the simulations and the PDU logger at the same node. When launch conditions determined from PDU data were compared for the various nodes, there was excellent agreement, due to the small latencies between PDU loggers. Total latencies (from simulation to simulation) for all entity state data and for the Fire (Missile) PDU must be less than about 50-100 msec to achieve good agreement between the shooter and target on all launch conditions (good agreement is defined to represent achievable differences: launch range within 100 ft, shooter altitude within 10 ft, and target aspect angle and lead angle within 1 °; most of these differences are 10%, or less, of the shot box tolerances given in Table 4.1.1.2-1).

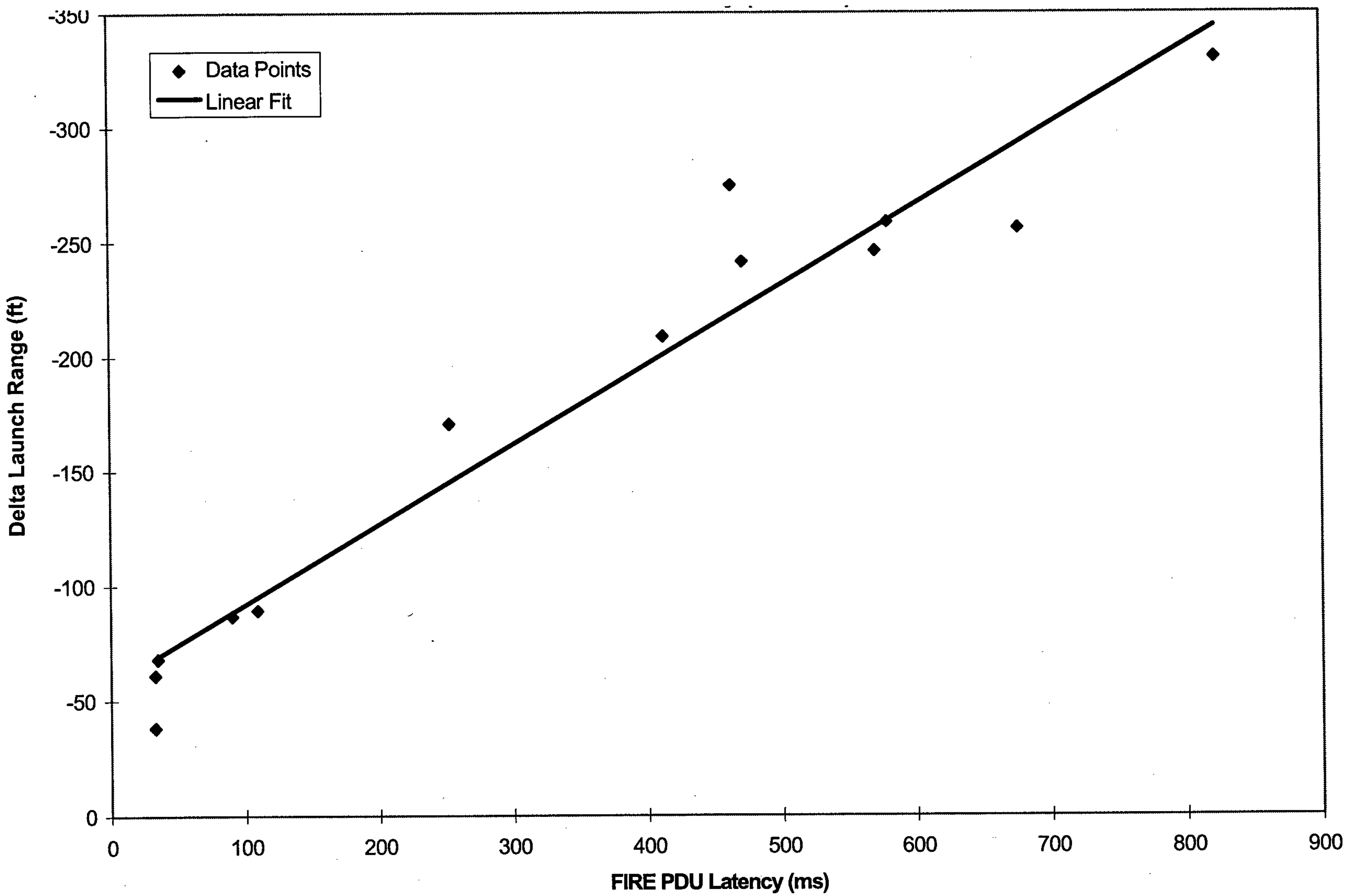


Figure 4.3.3.2.2-1. Launch Range from SIMLAB PDU Data Relative to Launch Range from SIMLAB Simulation Data vs. Fire (Missile) PDU Latency (10/29/96)

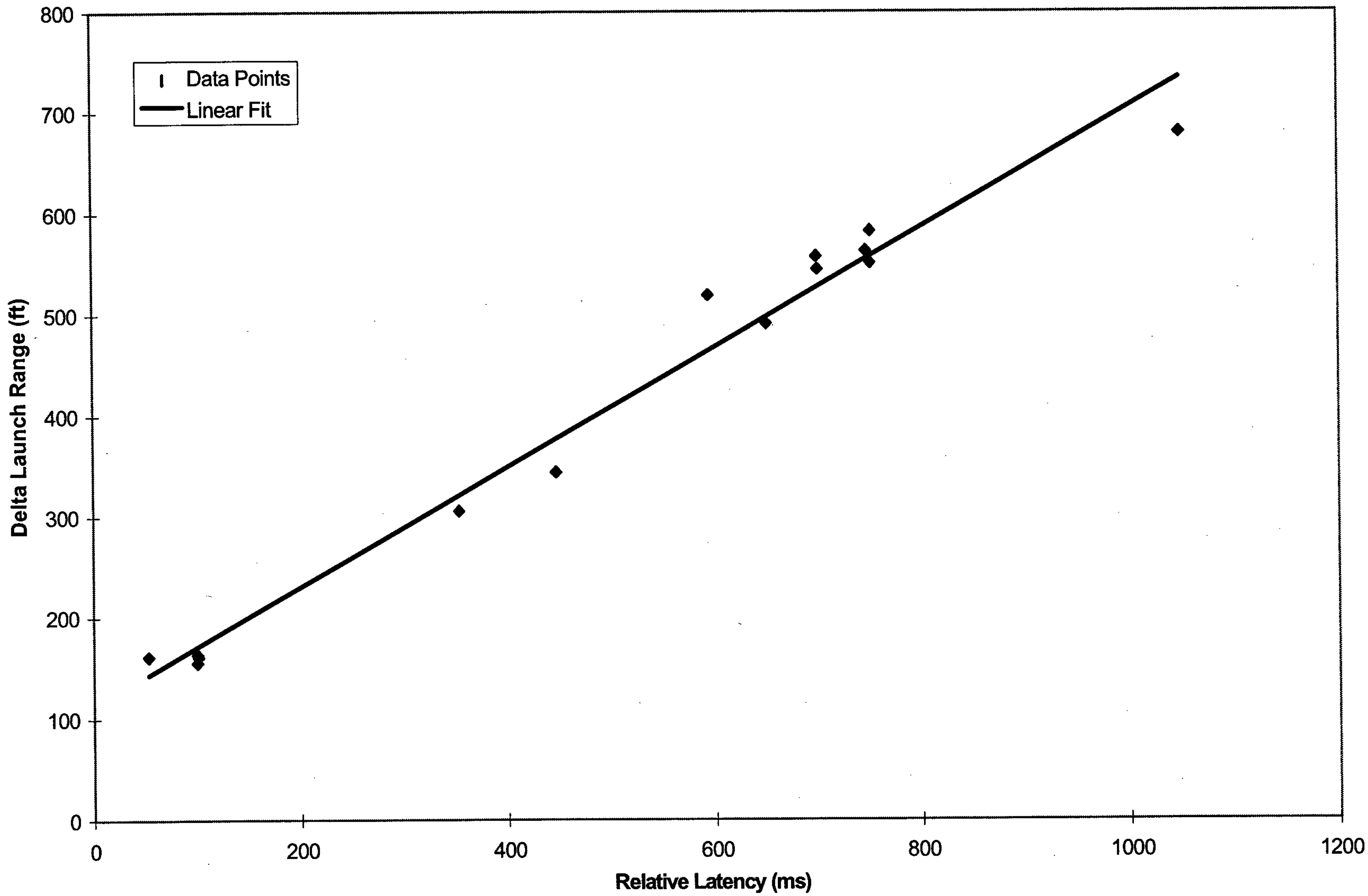


Figure 4.3.3.2.2-2. Launch Range from SIMLAB Simulation Data Relative to Launch Range from WSSF Simulation Data vs. Shooter Entity State Data Latency at SIMLAB Relative to SIMLAB Launch Indication Latency (10/29/96)

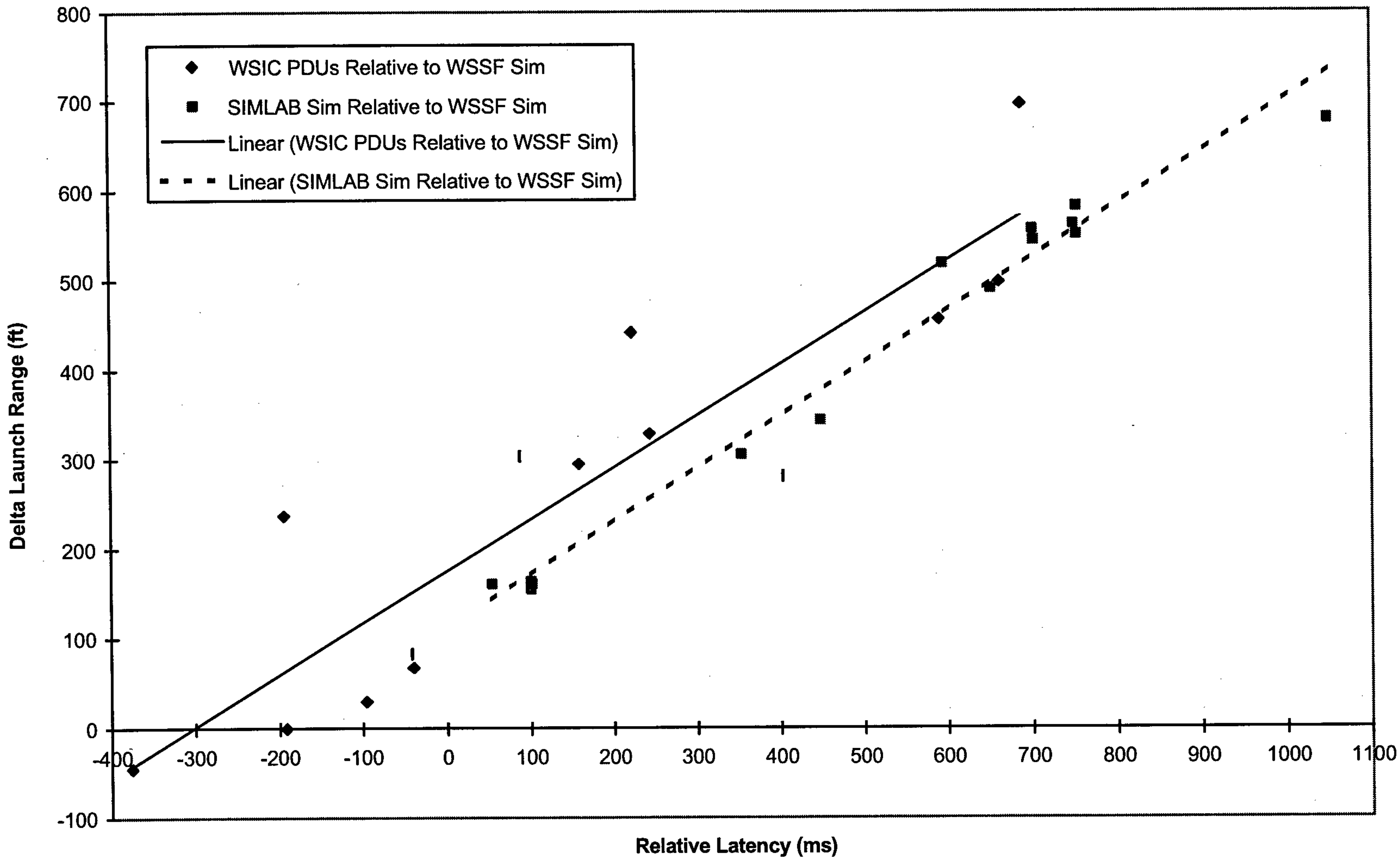


Figure 4.3.3.2.2-3. Launch Range from Various Data Sources Relative to Launch Range from WSSF Simulation Data vs. Shooter Entity State Data Latency Relative to Launch Indication Latency (10/29/96)

Parametric Study Mission

SIMLAB Simulation Data Compared to WSSF Simulation Data . The differences between the launch conditions from the SIMLAB simulation and those from the WSSF simulation were computed and are given in Table 4.3.3.2.2-5. The launch conditions from the SIMLAB simulation were logged for each run. However, the launch conditions for the WSSF were not computed by the simulation and had to be determined after the test as for the V&V Mission. The entries for relative latencies in Table 4.3.3.2.2-5 are the differences between the latency of each type of data (i.e., launch indication, shooter entity state, or target entity state data) received at the SIMLAB simulation and the latency of the same type received at the WSSF simulation. However, note that in this case the relative launch indication latency and the relative shooter entity state data latency are only between the WSSF and the SIMLAB.

Table 4.3.3.2.2-5. Differences Between Launch Conditions from SIMLAB Simulation and Launch Conditions from WSSF Simulation (11/19/96)

					Relative Latencies (ms)		
Run #	Range (ft)	Sh Alt (ft)	Aspect (°)	Lead (°)	Launch	Shooter	Target
9	34.7	2.9	0	-0.27	69	78	30
10	26.3	0.5	-0.16	-0.21	31	79	179
12	97.6	2.7	-0.15	-0.20	31	59	8
18	45.4	4.7	0.49	0.02	17	118	7
19	29.4	4.7	-0.69	0.04	17	117	107
22	34.6	1.7	-0.45	-0.43	9	108	71
Mean	44.7	2.9	-0.16	-0.18	29.0	93.2	67
Std Dev	26.7	1.7	0.40	0.18	21.4	24.5	67.2

Table 4.3.3.2.2-5 shows excellent agreement for all launch conditions. This was due to the small latencies between the SIMLAB simulation and the WSSF simulation during the Parametric Study Mission. This table shows that latencies less than 100 msec resulted in excellent agreement between the shooter and missile on all launch conditions.

WSIC Simulation Data Compared to WSSF Simulation Data . The differences between the launch conditions from the WSIC simulation and those from the WSSF simulation were computed and are given in Table 4.3.3.2.2-6. The launch conditions for the WSSF were not computed by the simulation and had to be determined after the test as for the V&V Mission. Also, the launch conditions for the WSIC were not computed by the simulation and had to be determined after the test as follows:

- The launch event at the WSSF was determined by using the shooter altitude from the F/A-18 cockpit data display which appeared at trigger squeeze.
  - -- The shooter data frame logged by the WSIC simulation which had a shooter altitude closest to this value was located, and other shooter parameters were noted, along with the IRIG time of this frame.

-- The target data frame logged by the WSIC simulation with the same IRIG time as the shooter frame was located, and the target parameters were noted.

- The launch conditions were computed from the shooter and target data.

The entries for relative latencies in Table 4.3.3.2.2-6 are the differences between the latency of each type of data received at the WSIC simulation and the latency of the same type received at the WSSF simulation. However, note that in this case the relative launch indication latency is only for data transmitted from the WSSF to the WSIC, the relative shooter entity state data latency is only for data transmitted from the WSSF to the WSIC, and the relative target entity state data latency is only for data transmitted from the WSIC to the WSSF (these latencies are negative in Table 4.3.3.2.2-6 because the target data flow was from the WSIC to the WSSF, the opposite of the other data flows).

Table 4.3.3.2.2-6. Differences Between Launch Conditions from WSIC Simulation and Launch Conditions from WSSF Simulation (11/19/96)

					Relative Latencies (ms)		
Run #	Range (ft)	Sh Alt (ft)	Aspect (°)	Lead (°)	Launch	Shooter	Target
9	42.0	-4.4	1.16	-0.52	236	146	-21
10	51.7	-3.3	2.34	-0.59	99	147	-14
12	126.2	-3.7	1.01	-0.80	194	122	-72
18	99.4	-1.2	1.20	-0.51	174	174	-22
19	65.7	-5.2	0.67	-0.50	174	122	-12
22	105.5	-4.2	1.32	-1.00	238	185	-9
Mean	81.8	-3.7	1.28	-0.65	185.8	149.3	-25
Std Dev	33.4	1.4	0.56	0.20	51.2	26.0	23.6

Table 4.3.3.2.2-6 shows good agreement for all launch conditions. Note that relative latencies in this table are larger than those in Table 4.3.3.2.2-5 and that the differences in launch conditions in Table 4.3.3.2.2-6 are correspondingly larger. Also note that the target entity state data latency between the WSIC and the WSSF at launch was smaller than the mean value for data passed before launch (Table 4.3.3.1-12), but the latencies of the launch indication and the shooter entity state data passed in the opposite direction were much larger. Nevertheless, even with relative latencies up to about 200 msec, the agreement in the launch conditions was still good. (Note that these latency values represent a relaxation of the latency requirements implied by the V&V Mission results, 50-100 msec. Apparently, the combination of low latencies for all data sources resulted in less stringent latency requirements.)

<u>WSIC Simulation Data Compared to SIMLAB Simulation Data</u>. The differences between the launch conditions from the WSIC simulation and those from the SIMLAB simulation were computed and are given in Table 4.3.3.2.2-7. The launch conditions from the SIMLAB simulation were logged for each run. However, the launch conditions for the WSIC were not computed by the simulation and had to be determined after the test as discussed above. The entries for relative latencies in Table 4.3.3.2.2-7 are the differences between the latency of each type of data received

at the WSIC simulation and the latency of the same type received at the SIMLAB simulation. However, note that in this case the relative target entity state data latency was only for data transmitted from the WSIC to the SIMLAB (these latencies are negative in Table 4.3.3.2.2-7 because the target data was first generated at the WSIC and then received at the SIMLAB, so that the target data had a higher latency at the SIMLAB).

Table 4.3.3.2.2-7. Differences Between Launch Conditions from WSIC Simulation and Launch Conditions from SIMLAB Simulation (11/19/96)

					Relative Latencies (ms)		
Run #	Range (ft)	Sh Alt (ft)	Aspect (°)	Lead (°)	Launch	Shooter	Target
9	7.3	-7.3	1.16	-0.25	167	68	-51
10	25.4	-3.8	2.50	-0.38	68	68	-193
12	28.6	-6.4	1.16	-0.60	163	63	-80
18	54.0	-5.9	0.71	-0.53	157	56	-29
19	36.3	-9.9	1.36	-0.54	157	5	-119
22	70.9	-5.9	1.77	-0.57	229	77	-80
Mean	37.1	-6.5	1.44	-0.48	156.8	56.2	-92.0
Std Dev	22.5	2.0	0.62	0.14	51.5	26.0	58.1

Table 4.3.3.2.2-7 shows very good agreement for all launch conditions. Note that the target entity state data latency between the WSIC and the SIMLAB at launch was comparable to the mean value for data passed after launch (Table 4.3.3.1-13), but the relative latencies of the launch indication were much larger. Nevertheless, even with relative latencies up to about 150 msec, the agreement in the launch conditions was still very good.

Comparisons Between Logged PDU Data . The differences between the launch conditions from PDU data logged at various locations were computed and were found to be in excellent agreement, as in the V&V Mission (Table 4.3.3.2.2-4).

SIMLAB Simulation Data Compared to "No Latency" PDU Data . Finally, the differences between the launch conditions from the SIMLAB simulation and those from entity state PDUs according to PDU time were computed and are given in Table 4.3.3.2.2-8. The shooter and target entity state PDUs were identified which had the same PDU time as the Fire (Missile) PDU. Note that these PDUs were being created at the WSSF and WSIC, respectively, at the time the Fire (Missile) PDU was created at the SIMLAB and had not yet come together at any one location for direct observation. Instead, computing the launch conditions from PDUs using the PDU time represented an approximation of the "no latency" case which reflected where the shooter and target actually were at the instant of missile launch. The latencies in Table 4.3.3.2.2-8 are for the shooter entity state data between the WSSF and the SIMLAB and for the target entity state data between the WSIC and the SIMLAB.

Table 4.3.3.2.2-8 shows very good agreement for all launch conditions, even with latencies up to about 100 msec.

Table 4.3.3.2.2-8. Differences Between Launch Conditions from WSSF Simulation and Launch Conditions from PDUs Using PDU Time (11/19/96)

					SIMLAB Latencies (ms)	
Run #	Range (ft)	Sh Alt (ft)	Aspect (°)	Lead (°)	Shooter	Target
9	74.6	6.7	-0.47	-0.24	78	51
10	69.4	3.3	-1.76	-0.13	79	193
12	57.3	5.3	-0.52	-0.10	59	80
18	97.0	8.2	-0.18	0	118	29
19	68.2	8.1	-0.89	-0.01	117	119
22	62.4	3.9	-0.69	-0.61	108	80
Mean	71.5	5.9	-0.75	-0.18	93.2	92.0
Std Dev	13.9	2.1	0.55	0.23	24.5	58.1

CONCLUSION. The small and stable latencies achieved in the Parametric Study Mission resulted in good agreement in the launch conditions determined by the various simulations (within 10% of shot box tolerances). This was true even though latencies as large as about 200 msec were observed between simulations for some of the data. In particular, the shooter and target simulations were in sufficient agreement to allow this ADS architecture to be used for pre-launch, closed-loop interactions, such as rehearsal and refinement of live engagement scenarios.

4.3.3.2.3 Terminal Engagement Conditions Differences Between Nodes

The terminal range was the range between the missile and the target when the SIMLAB simulation stopped the missile flyout. Typically, the missile had a time to go of 100 msec at this time. The terminal range was not the miss distance. Rather, the miss distance was estimated in the SIMLAB simulation by dead reckoning the missile and target velocities from the terminal range until the distance of closest approach was obtained. The last missile entity state PDU was generated when the missile reached the terminal range and the missile flyout ended, and this PDU was transmitted repeatedly from the SIMLAB for about one second after the end of the missile flyout.

The terminal range was computed from logged PDU data using the following steps:

- The first repeating missile entity state PDU at a node was identified.
  - -- This indicated the end of the missile flyout.
  - -- Initially, the Detonation PDU was to be used. However, this was found to be generated up to one second after the end of the missile flyout.
- The next logged target entity state PDU was identified.
- The terminal range between the missile and target was computed using the PDU positional data.

Initially, the terminal range computed from the entity state PDU data was to be compared to the terminal range determined by the SIMLAB simulation. However, two problems with the SIMLAB simulation prevented this direct comparison: the error in initializing the target position in the SIMLAB simulation reference frame and the latitude divergence problem (Section 4.1.1.3). Instead, the terminal range derived from entity state PDUs logged at the WSIC were compared to those derived from entity state PDUs logged at the SIMLAB. This comparison should provide some insight into how well the missile and target simulations might agree on miss distance. The results from the Parametric Study Mission are given in Table 4.3.3.2.2-9. The relative latency of the missile entity state PDUs (difference between latency at WSIC and latency at SIMLAB) is given in the table as a representative latency.

Table 4.3.3.2.2-9. Differences Between Terminal Range from PDUs Logged at WSIC and Terminal Range from PDUs Logged at SIMLAB (11/19/96)

Run #	Terminal Range Difference (ft)	Relative Missile Latency (ms)
9	32.0	19
10	0	18
12	37.2	17
18	0	15
19	0	16
22	35.6	18

Table 4.3.3.2.2-9 shows the following:

- The terminal ranges from PDU data agreed exactly on half of the runs. This resulted when the same pair of missile and target entity state PDUs were used to determine the terminal range at the two nodes. This could occur because the time between entity state PDUs was about 50 msec, and the relative missile latency was significantly less than that.
- The non-zero range differences resulted when the target entity state data from the WSIC logger was from the next generated PDU, as compared to the PDU used from the SIMLAB logger. Note that the same missile entity state PDU was always used at both nodes.
- The non-zero differ ences exceed the lethal radius for the missile, so that in those cases, it was possible for the missile and target nodes to disagree on whether or not the target was killed. Hence, terminal engagement results for a closed-loop interaction between the missile and target would be invalidated.

4.3.3.2.4 Synchronization of Simulations

The simulations could only be synchronized within the PDU update time (50 msec during the Parametric Study Mission). The simulations ran at higher rates, but could only exchange information at this rate. Hence, any simulation-to-simulation latency of less than 50 msec would have resulted in the simulations being synchronized to the degree possible. In other words,

latencies less than 50 msec allow a receiving simulation to be using the most current set of PDU data from a transmitting simulation.

The latencies evaluated between simulations (Tables 4.3.3.1-12 and 4.3.3.1-13) showed that they were usually running one PDU update time behind each other during the Parametric Study Mission. However, there were instances during a run in which one of the simulations was as many as seven PDU update times behind the other.

True synchronization of the simulations would require (1) that the PDU update rate equal the simulation frame rate of the fastest simulation, (2) that the frames of the individual simulations be synchronized to start at the same time (this also requires that the simulation frame rates all be the same), and (3) that the simulation-to-simulation latencies be less than the simulation frame time of the fastest simulation. Since the frame time of the SIMLAB simulation was less than 1 msec, the PDU update rate would have to be greater than 1 kHz and the latencies would have to be less than 1 msec. Such latencies cannot be achieved with simulation facilities separated by more than 100 miles.

4.3.4 Latency Study Summary

Improvements in the NIU settings and operations allowed the latencies to be greatly reduced by the Parametric Study Mission. The latencies exhibited significant sample-to-sample variations during a run (the standard deviation of the latency was a significant fraction of the mean value). Much, but not all, of this variation appeared to be caused by the interface between the simulation and the NIU at the receiving node.

The latency variations can distort entity state data received by a simulation, since the data was input into the simulation at the rate the data were received.

Latencies in the Parametric Study Mission were small enough (less than 200 msec between simulations) to allow the simulations to agree on the launch conditions to within less than 10% of the shot box tolerances. This indicates that the LSP architecture could be used for the rehearsal and refinement of launch conditions for live mission scenarios. However, the latencies were too large to allow reliable evaluation of the terminal engagement between the missile and target.

4.4 Test Objective 4: Assess ability of LSP ADS configuration to support AIM-9 testing

The test objective is broken into subobjectives as follows.

4.4.1 Test Subobjective 4-1: Assess capability of ADS network to provide bandwidth and connectivity required for LSP tests

This subobjective is to assess the ability of the LSP ADS network to support AIM-9 testing when it is operating.

4.4.1.1 Bandwidth and Connectivity Test Method

Data were collected for this subobjective during all the missions.

4.4.1.2 Bandwidth and Connectivity Analysis Method

Bandwidth Utilization

The average utilization was computed for each trial. Data for bandwidth utilization versus time was to be evaluated, but the non-availability of the appropriate network analysis tools prevented this.

Connectivity Loss

The number of trials during which connectivity was lost was determined, along with the duration of the loss.

4.4.1.3 Bandwidth and Connectivity Results

Typical bandwidth utilization was about 4% on the T1 connecting Point Mugu and China Lake. Bandwidth utilization on the WSSF and SIMLAB local area networks (LANs) was less than 2%, but about 50% on the WSIC LAN.

There was no loss of connectivity during the LSP missions.

4.4.2 Test Subobjective 4-2: Assess the effects of ADS-induced errors on LSP test results validity

4.4.2.1 ADS-Induced Errors Test Method

Data were collected for this subobjective during all the missions.

4.4.2.2 ADS-Induced Errors Analysis Method

Data from the missions were examined to determine if any ADS-induced errors had occurred. The ADS-induced errors which were anticipated prior to the missions included PDUs not received at the appropriate node or received out of order, PDUs corrupted during transmission, and entity state data errors introduced during the coordinate transformations required for entity state PDUs. The PDU data was examined for other errors or irregularities not anticipated.

4.4.2.3 ADS-Induced Errors Results

Missing PDUs

The counts of logged PDU data collected at the various locations were checked to determine if the number of PDUs transmitted by one node agreed with the number of PDUs received by another node. No instances of missing PDUs were found.

Out-of-Order PDUs

The logged entity state PDU data collected at the various locations were checked to determine if the PDUs for a given entity were received in the order they were created. This was done by arranging the logged PDUs by log time and noting whether or not the PDU time increased monotonically. No instances of out-of-order PDUs were found.

PDUs Corrupted During Transmission

The logged entity state PDU data collected at the various locations were checked to determine if the entity state data values for the same PDU agreed (PDUs were matched by PDU time). No instances of corrupted PDUs were found.

Coordinate Transform Errors

The net effect of transforming entity state data from the transmitting simulation reference frame to the PDU reference frame and then to the receiving simulation reference frame was evaluated in Section 4.1.1.3. The result was that the net error in transforming the positional data was 1-2 ft., and this was determined to be quite acceptable.

Repeating PDUs

As noted previously, some of the entity state data were found to contain repeating PDUs. These were PDUs which had the same PDU time and entity state data, but which were logged at receiving locations at different times (which implied that the repeaters were actually created at later times).

During the V&V Mission, repeating PDUs were noted for both the shooter and missile. In some cases, the PDUs repeated more than one time, resulting in "clumps." Examples are:

- Run #19 had 46 repeating shooter entity state PDUs out of 208 total PDUs. In one case, a shooter PDU repeated 5 times.
- Run #19 had 12 repeating missile entity state PDUs, and one repeated 5 times.
- Run #23 had 46 repeating shooter entity state PDUs out of 238 total PDUs.
- Run #23 had 9 repeating missile entity state PDUs, and one repeated 8 times (all the repeaters except one were in a single "clump").

During the Parametric Study Mission, repeating PDUs were also noted for both the shooter and missile. However, only single repeaters were noted; there were no "clumps." Characteristics of the repeaters were:

- Only three of the six complete V2 runs had repeating shooter entity state PDUs. The repeaters tended to occur well before missile launch, so that there were no repeaters near the launch time. Details are as follows:

-- Run #9 had 60 repeating PDUs out of 269 total. There were none during the last 5 sec before launch.
-- Run #10 had 3 repeating PDUs out of 2 53 total. There were none during the last 10 sec before launch.
-- Run #18 had 25 repeating PDUs out of 290 total. There were none during the last 10 sec before launch.

- Only two of the six complete V2 runs had repeating missile entity state PDUs. In one case (Run #12) there was only one repeater out of 102 total PDUs. In another case (Run #18), there were only two repeaters out of 111 total PDUs.

The error caused by repeating entity state PDUs was causing the entity position to either "freeze" (if the receiving node was not dead reckoning the entity's location) or to "jump back" (if the receiving node had been dead reckoning the entity's location prior to receiving the repeater). For the LSP, the only entity state data being used by other simulations was the target's. Since the target entity state PDUs did not repeat, there were no errors in the simulations caused by repeating PDUs.

Irregular Entity State Data Update Rates

The PDUs were not created at precise rates by the NIUs. Instead, the time between creating PDUs varied, and in some cases, there were significant time gaps between PDUs. Statistics on the time intervals between PDUs are given in Tables 4.4.2.3-1 and 4.4.2.3-2.

Table 4.4.2.3-1. Time Interval Between Target Entity State PDUs (11/19/96)

	Target PDUs Before Launch (msec)				Target PDUs After Launch (msec)			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
9	51.5	18.4	27	152	53.5	34.2	27	360
10	51.6	20.2	26	240	53.8	24.8	26	240
12	52.0	21.4	26	272	55.3	33.0	27	239
18	50.0	15.0	27	65	56.5	35.2	28	362
19	50.1	13.0	27	90	55.9	32.0	27	299
22	51.7	21.3	26	240	54.1	25.4	26	213

Table 4.4.2.3-2. Time Interval Between Shooter and Missile Entity State PDUs (11/19/96)

	Shooter PDUs Before Launch (msec)				Missile PDUs (msec)			
Run #	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
9	50.5	5.3	47	100	60.2	6.0	39	83
10	50.0	2.0	47	53	60.0	3.5	51	69
12	50.5	8.6	47	200	60.2	29.5	9	130
18	50.3	4.2	47	100	61.1	12.6	48	186
19	50.0	2.1	47	54	60.0	2.3	47	72
22	50.0	2.2	47	54	60.2	3.8	41	79

The following is noted from Tables 4.4.2.3-1 and 4.4.2.3-2:

- The creation rate for the target entity state PDUs decreased slightly after missile launch (from a mean value of 19.6 Hz before launch to a mean value of 18.2 Hz after launch).
- There were significant variations in the creation rate of the target PDUs. Intervals of up to 360 msec were noted between PDUs.
- The shooter PDUs had the most stable creation rate, although gaps of up to 200 msec between PDUs were noted.
- The missile PDUs had a low mean creationrate of 16.6 Hz.

Variations in the entity state PDU rate from a creating simulation result in the input to a receiving simulation not being smooth. Long gaps between PDUs can result in errors in the receiving simulation as it dead reckons the position data (but not the velocity data).

The SIMLAB integrated the target velocity to determine the target position, and irregular velocity update rates resulted in errors in the computed target location. The effect of the irregular creation rate alone on the computed target location was estimated by comparing the integration of the north component of target velocity at the irregular creation rates actually observed during the Parametric Study Mission to the integration at a regular 20 Hz rate. The result was that, on the average, the location of the target from the integration of the irregular velocity update rates was about 8 ft north of the location of the target from the integration of a regular velocity update rate.

The irregular creation rate for the target entity state data noted in Table 4.4.2.3-1 was aggravated by variations in the latencies between the WSIC and the SIMLAB simulations and by a lack of synchronization between the rate at which the target entity state data were updated at the SIMLAB NIU and the rate at which these data were updated in the SIMLAB simulation (so that the most current entity state data were not always input into the SIMLAB simulation). The resulting update times for target velocity data into the SIMLAB simulation are given in Table 4.4.2.3-3.

Table 4.4.2.3-3. Time Interval Between Target Velocity Updates in SIMLAB Simulation (11/19/96)

	Target Data After Launch (msec)			
Run #	Mean	Std Dev	Min	Max
9	54.8	41.3	19	446
10	62.5	23.0	38	156
12	67.1	35.0	20	251
18	82.6	46.2	43	399
19	81.3	41.0	30	300
22	77.6	34.1	41	248

The following is noted from Table 4.4.2.3-3:

- The rates for updating the target velocity in the SIMLAB simulation were significantly lower than the creation rates of the target PDUs after missile launch (Table 4.4.2.3-1). The average rate of creating the PDUs was 18.2 Hz, but the mean update rate in the SIMLAB simulation was as low as 12.1 Hz for Run #19.
- The low velocity update rates contributed to the latitude divergence problem discussed in Section 4.1.1.3. The actual times between velocity updates were used to estimate the SIMLAB integration errors in Table 4.1.1.3-5.
- The latitude divergence discussed in Section 4.1.1.3 compared the SIMLAB-computed latitude of the target with the target latitude from PDU data input into the SIMLAB simulation. When the entity state PDUs were not updated at the SIMLAB, the target position (including latitude) were dead reckoned. Dead reckoning the target latitude resulted in the target position being located north of its actual location (the target north component of velocity was constantly decreasing with time, so that too large of a north velocity was used in the dead reckoning).
  -- The effect of the irregular PDU update rates on the target latitude is illustr ated in Figure 4.1.1.3-1. Note that the solid curve for the target latitude input into the SIMLAB simulation is not smooth, but displays some jagged features. This was due to the dead reckoning of the target latitude between PDU updates. When the latitude was finally updated, a discontinuous adjustment resulted.

<u>PDU Time Stamp Errors</u>

Occasionally, shooter entity state PDUs were logged which had the same PDU time, but different entity state data. Since the resulting PDU had an invalid PDU time, any latency determination based on the PDU time was also invalid. (Note that the simulations did not use PDU time; as they received data, they used it without regard to when the data were created.) However, this type of error was very infrequent (only detected two or three times during all of the LSP runs).

4.4.3 Test Subobjective 4-3: Assess adequacy of standard data protocols for LSP test

4.4.3.1 Data Protocol Adequacy Test Method

Data were collected for this subobjective during all the missions.

4.4.3.2 Data Protocol Adequacy Analysis Method

DIS PDUs were identified for use in the LSP and were deemed to be adequate for all data exchanges with the exception of the SMS data (for which no standard protocol exists).

Any bandwidth utilization problems identified under Subobjective 4-1 and any ADS-induced errors identified under Subobjective 4-2 were to be analyzed to determine if the structure, format, or processing of the PDUs was the cause of the error.

- The bandwidth required for the data in the high-f idelity simulation output format was to be compared to the same data in the PDU format. The data rate output directly from the

high-fidelity simulations was to be determined from data logged on the simulation computers. The data rate output from the NIU at each node was to be determined from the PDU data loggers. The differences were to be computed at several sample times during periods when bandwidth utilization problems occurred.

- High-fidelity-data-to-PDU conversion errors and PDU-to-high-fidelity-da ta conversion errors analyzed under Subobjective 4-2 were reviewed to determine if the source of the error was the reference frame conversions required for entity state PDUs.

4.4.3.2 Data Protocol Adequacy Results

Adequate tools were not available to identify specific periods of high bandwidth utilization. However, the typical bandwidth utilization on the T1 connecting Point Mugu and China Lake was relatively low (~4%). This indicated that use of the PDUs did not result in bandwidth utilization problems.

The coordinate transform errors associated with the use of entity state PDUs were small (1-2 ft) and deemed to be quite acceptable.

Data PDUs were used to transmit test control display data from the WSSF and WSIC to the TCAC. The data PDUs did an adequate job of transmitting these data.

CONCLUSION. The DIS PDUs used in the LSP were adequate for the required data exchanges.

4.4.4 Test Subobjective 4-4: Assess reliability, availability, and maintainability of ADS network

Reliability, availability, and maintainability (RAM) data were gathered for all components that made up the LSP ADS configuration at each node as well as the linking network. The data gathered at each of the four nodes, (BMIC/TCAC, WSIC, WSSF, and SIMLAB) consisted of all network-related hardware and software failures which occurred during the test events. Failures of the high-fidelity simulations themselves were not included.

4.4.4.1 RAM Test Method

Data, as shown in Table 4.4.4.1-1, were collected for this subobjective during all the missions. Operator logs, maintenance logs, and test director logs were the major sources of data.

Table 4.4.4.1-1. Reliability, Availability, and Maintainability Data Requirements

Data Requirement	Definition
Machine Name	Name of hardware that failed
Program/Device Name	Name of software with fault and device it was running on
Failure Type	Either hardware failure or software fault
Mission Start or Last Time Up	Either time when mission started (if first failure during mission) or last time when entire ADS network was available (if not first failure)
Time of Failure (TF)	Time during mission when failure occurred
Time Repair Complete	Time when repair of hardware failure or software fault is completed
Time Up (TU)	Time when network is available to resume testing

4.4.4.2 RAM Analysis Method

The RAM of the LSP ADS configuration was assessed. Although component RAM data were gathered, only overall system and linking network RAM are reported due to the limited test time available. Individual RAM data are not reported for the three simulators used in this test. The entire ADS configuration and network, not the simulators, were the focus of this study.

The data indicated in Table 4.4.4.1-1 were to be used to calculate: Availability (A_o), Reliability expressed as Mean Time Between Operational Mission Failures (MTBOMF), and Maintainability expressed as Mean Corrective Maintenance Time for Operational Mission Failures (MCMTOMF). Both MTBOMF and MCMTOMF were to be broken down into both hardware and software failures and repairs.

Availability The parameter for addressing availability (A_o) were calculated as:

$$A_o = \frac{\text{Up Time}}{\text{Up Time} + \text{Down Time}} \tag{7}$$

- Up Time was that time duration when the system was considered to be ready for use and was either operating or in standby (in an up status).
  - -- Each increment of Up Time was computed from the difference between the last Time Up (TU) and the next Time of Failure (TF).
  - -- The increments of Up Time were added to give the total Up Time for (1) each mission and for (2) all LSP missions.
- Down Time was that time duration when the system was down for repair of operational mission hardware failures and/or for restoration from operational mission software faults.
  - -- Down Time includes time to detect failure, investigation time, reporting time, time awaiting repair, fault-fix time, restart time, and checkout time.
  - -- Each increment of Down Time was computed from the difference between the next Time Up (TU) and the last Time of Failure (TF).

Reliability. The parameters for addressing reliability ($MTBOMF_{SYSTEM}$, $MTBOMF_{HW}$, and $MTBOMF_{SW}$) were to be calculated as:

$$MTBOMF_{SYSTEM} = \frac{\text{Total System Operating Time}}{\text{Number of Operational Mission Failures / Faults}} \quad (8)$$

- An operational mission failure/fault was one which precluded successful completion of a mission and included a hardware failure or a software fault.
- System Operating Time was to include all time that the system was operating or in standby. This was the same as the total Up Time during a mission.

$$MTBOMF_{HW} = \frac{\text{Total System Operating Time}}{\text{Number of Operational Mission Hardware Failures}} \quad (9)$$

- An operational missio n hardware failure was one which precluded successful completion of a mission.

$$MTBOMF_{SW} = \frac{\text{Total System Operating Time}}{\text{Number of Operational Mission Software Faults}} \quad (10)$$

- An operational mission software fault was one which precluded successful completion of a mission.

Maintainability. The parameters for addressing maintainability ($MCMTOMF_{HW}$ and $MCMTOMF_{SW}$) were to be calculated as:

$$MCMTOMF_{HW} = \frac{\text{Total Elapsed Time to Repair Hardware Failures}}{\text{Total Number of Operational Hardware Failures}} \quad (11)$$

- Repair time for hardware failures included maintenance preparation, fault location and isolation, fault correction, adjustment and calibration.

$$MCMTOMF_{SW} = \frac{\text{Total Elapsed Time to Repair Software Faults}}{\text{Total Number of Operational Software Faults}} \quad (12)$$

- Repair time for software faults was the time needed to restore all system processes, functions, files, and data bases to a useful state.

4.4.4.3 RAM Analysis Results

Availability. A summary of the periods of Up Time and Down Time for linked testing periods is given in Table 4.4.4.3-1. This table also summarizes results from the linked laboratory testing periods which were used to prepare for the missions.

Table 4.4.4.3-1. Summary of Periods of Up Time and Down Time for All Linked Testing

Date	Total Mission Time	Up Time	Down Time
27 Aug 96 (Rehearsal)	4 hr 14 min	4 hr 14 min	None
28 Aug 96 (Rehearsal)	4 hr 13 min	4 hr 6 min	7 min
22 Oct 96 (Lab Time)	1 hr 52 min	1 hr 40 min	12 min
29 Oct 96 (Mission)	3 hr 55 min	3 hr 13 min	42 min
12 Nov 96 (Lab Time)	1 hr 43 min	1 hr 43 min	None
19 Nov 96 (Mission)	3 hr 45 min	1 hr 54 min	1 hr 51 min
Totals	19 hr 42 min	16 hr 50 min	2 hr 52 min

As Table 4.4.4.3-1 shows, the total Up Time for the mission rehearsal, the two missions and the two formal linked laboratory periods was 16 hours and 50 minutes, and the total Down Time was 2 hours and 52 minutes. Using these values in Equation 7 gives an average availability of 85.4%.

Reliability. There were no operational mission failures/faults. Hence, the reliability parameters ($MTBOMF_{SYSTEM}$, $MTBOMF_{HW}$, and $MTBOMF_{SW}$) could not be calculated. However, it can be noted that these mean times between operational mission failures must exceed the total mission time of 19 hours and 12 minutes.

Maintainability. A summary of the times to repair the hardware failures is given in Table 4.4.4.3-2, and a summary of the times to repair the software faults is given in Table 4.4.4.3-3. Note that these failures/faults all resulted in Down Time, so that the total repair time equals the Down Time.

Table 4.4.4.3-2. Summary of Repair Times for Hardware Failures

Date	Hardware Failure Details	Repair Time
29 Oct 96 (Mission)	Power Loss in TCAC	15 min
19 Nov 96 (Mission)	WSIC blower loss	24 min
19 Nov 96 (Mission)	AIM-9 Seeker Failure (Connector Problem)	58 min
Total	3 hardware failures	1 hr 37 min

As Table 4.4.4.3-2 shows, the total time to repair three hardware failures was 1 hr 37 min. Using these values in Equation 11 gives $MCMTOMF_{HW}$ = 32.3 min.

Table 4.4.4.3-3. Summary of Repair Times for Software Faults

Date	Software Fault Details	Repair Time
28 Aug 96 (Rehearsal)	SIMLAB NIU required reset	4 min
28 Aug 96 (Rehearsal)	SIMLAB NIU required reset	3 min
22 Oct 96 (Lab Time)	WSSF NIU required reset	2 min
22 Oct 96 (Lab Time)	MNS-1 (SMS link) required reset	4 min
22 Oct 96 (Lab Time)	SIMLAB NIU required reset	5 min
22 Oct 96 (Lab Time)	SIMLAB NIU required reset	1 min
29 Oct 96 (Mission)	SIMLAB NIU required reset	1 min
29 Oct 96 (Mission)	WSIC simulation data logging system crash	16 min
29 Oct 96 (Mission)	SIMLAB NIU required reset	1 min
29 Oct 96 (Mission)	SIMLAB simulation computer crash (over heat)	5 min
29 Oct 96 (Mission)	WSIC simulation required reset	4 min
19 Nov 96 (Mission)	WSIC simulation required reset	16 min
19 Nov 96 (Mission)	WSIC simulation required reset	4 min
19 Nov 96 (Mission)	SIMLAB simulation computer crash	8 min
19 Nov 96 (Mission)	SIMLAB simulation computer crash	1 min
Total	15 software faults	1 hr 15 min

As Table 4.4.3-3 shows, the total time to repair 15 software faults was 1 hr 15 min. Using these values in Equation 12 gives $MCMTOMF_{SW}$ = 5.0 min.

4.4.5 Test Subobjective 4-5: Assess capability for centralized test control and monitoring

4.4.5.1 Test Control Test Method

Data were collected for this subobjective during all the missions.

4.4.5.2 Test Control Analysis Method

The ability to exercise the control and monitoring functions were assessed. The following were analyzed during each mission and rehearsal:

- Ability to coordinate the start and stop of each simulation run. Could the start and stop of all simulation facilities be coordinated with sufficient synchronization?
- Ability to maintain communications between all nodes. Were comm unications to any facility lost at any time?
- Ability to monitor status of each simulation facility during mission. Could the operational status of each facility be monitored continuously and in real-time during each mission?
- Ability to monitor analog and discrete data channels from simulation facilities. Were the data from these channels sufficient to remotely monitor simulation performance?
- Ability to verify profile execution and data collection between trials. Were the quick-look results sufficient to verify that the planned profile was executed within acceptable tolerances? Were the quick-look results sufficient to verify that all required data were

obtained? Were the quick-look results available in a timely manner (within 5 minutes of trial completion)?

4.4.5.3 Test Control Analysis Results

4.4.5.3.1 Control Procedures

Test control procedures were designed for simplicity and decentralization of control. The design of the test required the shooting aircraft to achieve a certain geometry where altitude, airspeed, range to target, target aspect, missile pointing angle and target acceleration were simultaneously achieved. The only way these conditions could be repeated consistently was if the shooter pilot controlled the entire intercept. To reduce the number of variables he had to deal with, the shooter pilot was "unfrozen" at a specified distance aft of the target with approximately a half mile of lateral separation (see Fig. 4.4.5.3.1-1). After both simulators were reset and frozen, the target simulation was started. The shooter watched his HUD as the target range opened. When he saw the range to target he wanted, he unfroze his own simulation. This procedure was used instead of simultaneously unfreezing both simulations since the time required to unfreeze the target simulation took from less than a second to up to 3 seconds. This procedure permitted the shooter to achieve a consistent starting geometry without having to make a difficult and time consuming speed adjustment to achieve proper range. The initial altitude difference and lateral separation were determined by trial and error.

When the test controller saw both aircraft "flying," he called for the target to turn and cross in front of the shooter (see Fig. 4.4.5.3.1-1). The target then flew a turn at constant speed, altitude and turn acceleration. This flight path, combined with the initial conditions of each simulator, allowed the shooter to achieve the desired range and aspect parameters with little maneuvering. This was critical since too much rolling by the F/A-18 pushed the SIMLAB HWIL missile beyond the limits of the Carco table.

Once the test controller had started the target turning, achieving the desired geometry was totally under the control of the F/A-18 pilot. After the missile finished its flyout the test controller terminated the run and released the simulators to reset following any quick look procedures they needed to perform.

All analysts were located in the SIMLAB where the data from the missile were presented. The only communication required from the SIMLAB was a statement on whether the run was acceptable or not.

This control approach resulted in minimal communications on the unclassified command voice circuit.

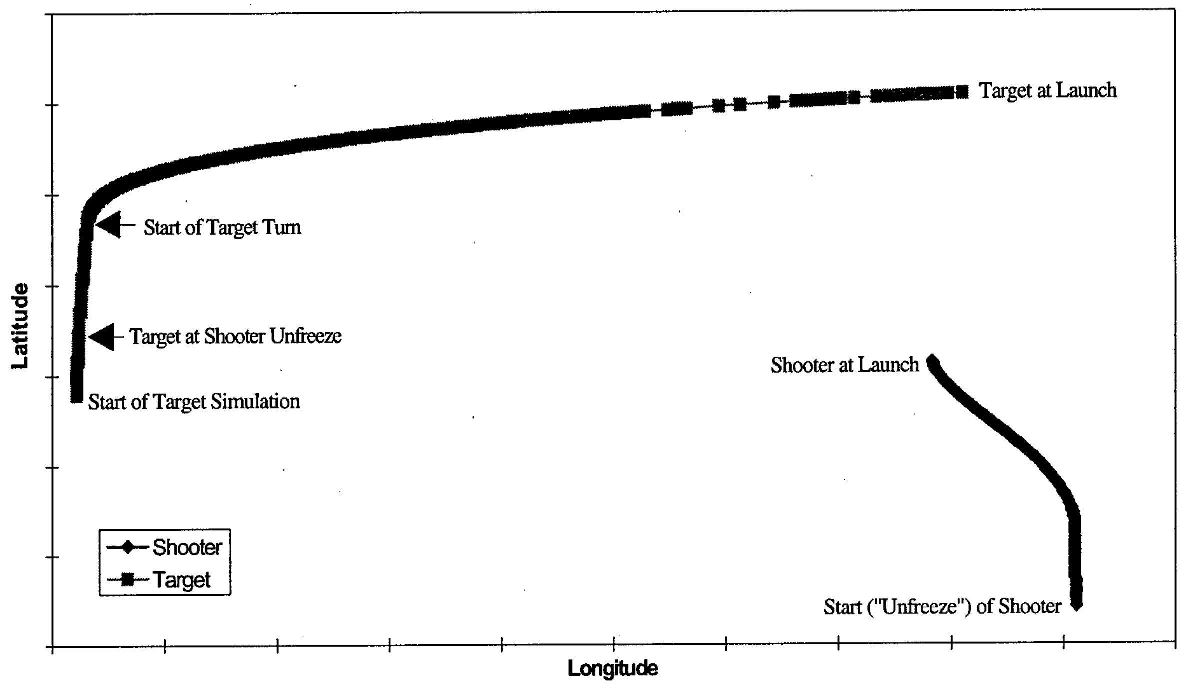


Figure 4.4.5.3.2-1. Pre-Launch Shooter and Target Trajectories (Run #9 on 11/19/96) - "God's-Eye" View

4.4.5.3.2 Test Monitoring Displays

Two separate displays were developed to permit effective control of the tests and to evaluate how well each intercept was performed.

- The first display was a two-dimensional ("God's-eye") stealth viewer. Entity state PDUs from the two aircraft and the missile, after it was fired, were displayed on a screen showing an outline of the China Lake restricted airspace. Since both players were virtual, the exact location did not matter. Each entity was represented by a friendly or hostile symbol with an aspect vector whose direction represented the entity heading and whose length was proportional to the speed. Each entity created a "trail" of points representing its flight path. Because the LSP was attempting to replicate a single profile, the ground track for each run essentially overlaid the tracks of the previous runs. This provided a useful capability for making a first cut evaluation of how well the intercept and flyout replicated the desired trajectories.

- The other "discretes" display showed various parameters which defined the "shot box." Target altitude, mach number, and turning acceleration, long with shooter altitude and mach number were displayed in strip chart format with a total of 16 seconds of history trace visible at a time. A horizontal blue line was displayed continuously for the desired value for each parameter throughout the period when the instantaneous value was being displayed. A digital readout for each parameter was also provided. When each parameter

fell within the desired range of values which defined the shot box, the digital readout turned from white to green.

The speed with which the shooter was closing on the target (V_c) was also displayed in this manner; however, this parameter turned out not to be useful.

The radar mode and status of master arm power and the trigger were listed in gray and turned green when selected or the trigger was squeezed.

Range to target was shown to one decimal place of precision. The numbers were green when within the desired range.

The true heading of each aircraft was displayed in digital format.

Two circular displays showed (a) where the radar was pointing relative to the nose of the aircraft both in azimuth and elevation and (b) the angle between the nose of the target and the line-of-sight to the shooter (i.e., the target aspect angle).

The radar pointing angle was used as a reasonably close measure of how far off boresight the missile seeker was pointing since the seeker was slaved to the radar line-of-sight at launch.

Each display turned from white to green when the particular parameter met acceptable launch conditions. This provided a very simple and accurate method of determining whether the particular run met the desired parameters. However, the final decision on whether to count the run as "in the shot box" rested with the analysts in the SIMLAB.

4.4.5.3.3 Test Control Evaluation

Each bullet in Section 4.4.5.2 is addressed below.

- **Ability to coordinate the start and stop of each simulation run.** Successful. **Could the start and stop of all simulation facilities be coordinated with sufficient synchronization?** Yes, this was straight forward. Each site supervisor reported ready on the command voice net. The Test Controller counted down to a "start run" call. Since all the site and laboratory supervisors and both pilots were on the command voice circuit, close coordination was achieved. A verbal call to the Network Coordinator, who was sitting next to the Test Controller in the TCAC, to start and stop the data recorders ensured all recorders were running before the pilots started flying and not turned off until after the missile had completed its flyout.

- **Ability to maintain communications between all nodes.** Successful. **Were communications to any facility lost at any time?** While it would have been preferable to have secure communications between all participants on the command net, the test was successfully accomplished at the unclassified level. A lack of phone lines in some areas of the laboratories required using splitters with the resultant decrease in audio levels. This

was an inconvenience; however, due to the simple nature of the procedures this was not a problem. For more complex tests a more robust, reliable (and expensive!) communications system would be required.

- **Ability to monitor status of each simulation facility during mission.** Successful. **Could the operational status of each facility be monitored continuously and in real-time during each mission?** Yes. The operational status of each facility was apparent from the communications on the command net. There was no need for remote monitoring of the various simulation computers or other components. The Network Coordinator was able to monitor the status of the routers and PDU loggers remotely from the TCAC using NetSnoop and NetVis software. It was also evident fairly quickly on the stealth viewer if one of the entities was not putting out PDUs.

- **Ability to monitor analog and discrete data channels from simulation facilities.** Successful. **Were the data from these channels sufficient to remotely monitor simulation performance?** The display described previously provided sufficient information for a test controller (who was a pilot) to visualize the progress of the intercept. It was designed to provide the essential elements of information which were displayed in the aircraft HUD. During one of the rehearsal missions the Test Controller happened to be located in the SIMLAB with a HUD repeater, but no stealth viewer. This configuration worked well also, even without any direct readout of parameters from the target aircraft. This display was not designed to monitor any performance parameters internal to each simulation. This was done by the laboratory supervisor at each site.

- **Ability to verify profile execution and data collection between trials.** Successful. **Were the quick-look results sufficient to verify that the planned profile was executed within acceptable tolerances?** Yes. The two-dimensional viewer permitted immediate evaluation of whether or not the missile guided. As mentioned above, the trail feature provided a template of the proper trajectories. In the case of the SIMLAB, the physical limitations of the Carco table were such that either the missile guided to intercept or the table mirrors exceeded a mechanical limit during flyout and the missile "stopped" flying while pointing on a heading which was clearly inappropriate. The parameter display was sufficient to evaluate whether all the parameters of the shot box were met. Again, the analysts in the SIMLAB had the final say on whether the run was within the shot box. **Were the quick-look results sufficient to verify that all required data were obtained?** Yes. Following each run, the F/A-18 and SIMLAB supervisors recorded launch and flyout data from displays in the cockpit or laboratory. The simulations were not reset for the next run until all data had been recorded. **Were the quick-look results available in a timely manner (within 5 minutes of trial completion)?** Yes. The recording process took two or three minutes at the most.

4.5 Analysis Summary

Test Objective 1: Assess the validity of AIM-9 data obtained in the LSP ADS configuration

- Verification
  - -- The simulation facilities were properly linked.
  - -- The errors in transforming from the raw simulation positional data to entity state PDU data were 1-2 ft, and these errors were acceptable.
  - -- There were no errors in transforming velocity and orientation data.
  - -- There were no PDU transmission errors.
  - -- There were several errors in the target positional data presented to the SIMLAB simulation.
    - --- Random latency variations introduced uncertainty in the target position. The random nature of these variations prevents the future implementation of a deterministic real-time correction for all latency effects.
    - --- The target latitude determined by the SIMLAB simulation diverged from the WSIC value during the missile flyout. This appeared to be fixable by using a more sophisticated target velocity integration technique and by using higher velocity update rates.
    - --- The target representation in the SIMLAB simulation coordinate frame was wrong due to an error in the coordinate transformation. This was subsequently fixed.

- Validation
  - -- The SIMLAB standalone simulations of the LPN-15 engagement were valid.
  - -- The planned quantitative validation technique based on comparing the missile flyouts from the linked runs to the envelopes resulting from Monte Carlo sampling of launch conditions had to be abandoned. It was incapable of identifying many of the invalid lofting missile trajectories.
  - -- The validation approach was modified to include both qualitative and quantitative validation methods.
    - --- Features in the LPN-15 missile flyout were used for qualitative validation of the linked results.
    - --- Quantitative validation compared the missile flyout results of a single linked run to the envelope of 20 SIMLAB standalone runs which all used the same launch conditions and target trajectory as the linked run.
  - -- Applying the qualitative method to the Parametric Study Mission V2 runs showed that the missile flyouts were valid for the target representation in the SIMLAB reference frame.
  - -- Applying the quantitative method to the best of the Parametric Study Mission V2 runs showed that the missile flyouts from the linked runs were invalid because the target representation in the SIMLAB reference frame was in error.
    - --- Errors in initializing the target and missile in the SIMLAB reference frame were not discovered until after the linked runs were completed and have since been fixed.

--- Validity of the missile flyout can be further improved by more accurate SIMLAB integration of the target velocity to determine target position.

-- Missile TOF gave a better metric for quantifying overall missile behavior than did the miss distance.

Test Objective 2: Assess utility of LSP ADS configuration for parametric studies

- The manual method for replicating a given profile resulted in very good run-to-run reproducibility of the launch conditions.
  - -- The distribution of launch conditions results was significantly tighter than the shot box tolerances for all parameters.
- The automatic replay method was unable toprecisely replicate a given scenario.
  - -- In order for the automatic replay method to be effective, the manual actions required in the LSP trials need to be replaced with automatic procedures. This was beyond the scope of the LSP, but future implementations of this concept may be able to overcome this limitation.

Test Objective 3: Assess effect of latency on validity of test results

- Latency Characteristics
  - -- The mean latencies of the entity state data in early missions were large with large sample-to-sample variations during a run. Shooter entity state data exhibited very high latency "spikes" with latencies up to ~1 sec.
    - --- Most of the latency contribution was between the creating simulation and the NIU where PDUs were created from the raw simulation data.
    - --- Transmission latencies between NIUs at different nodes were relatively small (~20 msec).
  - -- The mean latencies of all entity state data from the Parametric Study Mission were relatively small and consistent run-to-run.
    - --- The latencies between any pair of nodes still exhibited relatively large sample-to-sample variations (relative to the mean value), and high latency "spikes" were still observed (but were typically only up to ~100 msec).
    - --- The latency of the target entity state data between the NIU at a receiving node and the receiving simulation was about twice the value between NIUs.

- Latency Effects
  - -- Entity Presentation Errors
    - --- Random variations in latency between the WSIC and the SIMLAB during a run resulted in an uncertainty in the target location, as perceived in the SIMLAB.
    - --- Entity velocity data exhibited discontinuous changes.
  - -- Launch Conditions Differences Between Nodes
    - --- Large latencies in the early missions (>200 msec) resulted in significant disagreements in the launch conditions perceived by different simulations.

--- The small and stable latencies in the Parametric Study Mission (<200 msec) resulted in very good agreement in the launch conditions perceived by different simulations. Differences were typically less than 10% of the shot box tolerances.

--- The Parametric Study Mission results show that the shooter and target simulations were in sufficient agreement to allow the LSP architecture to be used for pre-launch, closed-loop interactions, such as rehearsal and refinement of live engagement scenarios.

-- Terminal Engagement Conditions Differences Between Nodes

--- The error in initializing the target location in the SIMLAB simulation and the latitude divergence problem prevented a direct comparison of the terminal range as determined by the SIMLAB simulation with the terminal range as determined by entity state data logged at other locations.

--- Results from entity state PDU data collected at different nodes imply that terminal engagement results for a closed-loop interaction between the missile and target would be invalid.

Test Subobjective 4-1: Assess capability of ADS network to provide bandwidth and connectivity required for LSP tests

- Typical bandwidth utilization was low (~4%) on the T1 connecting Point Mu gu and China Lake.
- There was no loss of connectivity during the LSP missions.

Test Subobjective 4-2: Assess the effects of ADS-induced errors on LSP test results validity

- There were no missing or out-of-order PDUs.
- The errors associated with transforming the entity state data from the simulation reference frame to the PDU reference frame and back again were small and acceptable (1-2 ft.).
- Repeating shooter entity state PDUs occurred. However, the repeaters stopped 5-10 sec before launch, so that no errors were caused in the launch conditions.
- The PDU update rates for the various entities were irregular. This aggravated the target latitude divergence problem.

Test Subobjective 4-3: Assess adequacy of standard data protocols for LSP test

- The DIS PDUs used were adequate for exchanging information between the simulations and for providing data for the test control displays.

Test Subobjective 4-4: Assess reliability, availability, and maintainability of ADS network

- The average availability of the ADS network for all linked testing was 85.4%, a very acceptable value.
- There were three hardware failures, and the average time for repairing them was 32 min.
- There were 15 software faults, and the average time for repairing them was 5 min.

Test Subobjective 4-5: Assess capability for centralized test control and monitoring

- The test control procedures worked quite well.
- Monitors provided to the BMIC/TCAC effectively supported test control.

5.0 LSP Lessons Learned

These lessons learned incorporate findings from the NAWCWPNS final report[2] verbatim.

5.1 Technical Lessons Learned

5.1.1 Simulations

- Accurate coordinate transformations are necessary. Accurate end-to-end coordinate transformations proved difficult at the beginning of the LSP. Coordinate transformations must be verified and validated at each site and then reverified and revalidated during end-to-end testing as early as possible in the test phase. Personnel who are subject matter experts in coordinate transformations must be assigned and readily available during this process.

- Quantitative validation has limitations. The JTF intent was to quantitatively verify missile simulation performance against live fire data. Given the facts that only a single live fly event was available to support the process and that the live engagement could not be perfectly replicated, it became necessary to modify the validation approach. The modified approach included both qualitative and quantitative methods (see Section 4.1.2.4) and successfully identified invalid results (lofting missile trajectories and target initialization errors).

5.1.2 Interfaces

- Network interfaces need improvement. Network Interface Units (NIUs) of some sort are necessary if two simulators cannot communicate directly in a common language, and on a common timeline. NIUs can be a major source of both error and processing delays. For the LSP, the NIUs were difficult to troubleshoot and control. Future projects should use an improved DIS NIU or an "NIU function" (in the master simulation computer) which provides a more direct user control of the content of the data and network communications, including the capability to force network communications at a user-specified frame rate. Such improvements could simplify the overall network/ADS configuration, as well as the troubleshooting and resolution of various network/ADS/DIS problems.

5.1.3 Networks

- Common ADS-related hardware and software is needed. It was difficult to get the ADS network to behave in a uniform fashion due to the many different types of interface hardware, communications equipment (routers), and interface software versions. In all major NAWCWPNS simulation operations previous to the LSP, all sites had exactly

[2] Joint Advanced Distributed Simulation Linked Simulator Phase Final Report, NAWCWPNS Report Ser 529100E/A-218, 16 January 1997.

duplicated network hardware and interface software, which is the preferred network architecture. However, program schedule and cost constraints required that the existing NAWCWPNS NRNet network be used for the LSP instead of building a network from "scratch." Additionally, lack of common software resulted in the NIUs having numerous and different problems related to conversions, timing, CPU speed, etc. Whenever possible for future ADS test, the network hardware and interface software should be exactly the same among all the sites.

- Latency variations were significant. Aggregate latency includes the transmission delays and the processing delays on each leg of the ADS architecture. Both the transmission-induced and processing components of latency exhibited significant random variations which cannot be compensated for, although the processing delays were the dominant source of latency. Future ADS implementations which require low latencies (e.g., interactive missile engagement analyses) should focus on techniques for reducing the latency between the network interface and the receiving simulations.

- Time sources must be synchronized. IRIG/GPS time must be synchronized off of the same time source and then must be validated at each test site prior to project operations to ensure accurate, synchronized time is precisely recorded at each test site. It took a lot of effort to get clock synchronization values into the few millisecond region, and meaningful latency measurements were impossible without this degree of clock synchronization.

5.1.4 Instrumentation

- Special test equipment is needed for checkout and verification. Special test equipment (e.g., SNAP loggers, DIS dataloggers, etc.) and other networking tools (e.g., Stealth Observer) should be part of each simulation node's configuration during the development, test, checkout, and verification/validation phases in all subsequent ADS testing. Special test equipment and networking tools are required to more rapidly isolate and determine the specific cause of network, ADS/DIS, etc. problems. Without the special test equipment and/or tools, trial and error becomes the normal troubleshooting mode which increases the resource requirements (time, schedule, cost, etc.). The equipment and tools also permit off-line testing without the exclusive scheduling of simulation laboratories and the associated costs. Individual test sites could then check their own software and hardware, verify PDUs and other ADS/DIS requirements, and verify program-specific requirements prior to the more costly linked tests. The special test equipment and networking tools developed and used by the JADS JTF for the LSP proved valuable once the equipment and tools became available to NAWCWPNS.

5.2 Infrastructure Lessons Learned

5.2.1 Procedures

5.2.1.1 Planning

- The requirements for an ADS test must be clearly defined early in the test planning phase
  - -- The user of test range assets (e.g., JADS) must clearly define, communicate, and document test requirements to the support agency (e.g., NAWCWPNS) early in the test planning phase. Also, the capability of the support agency to support the test must be clearly stated and documented.
  - -- OPSEC requirements for a distributed weapon system test must be determined and coordinated early in the program, especially with the various organizations and their different procedures. Issues to be addressed include: the need for an OPSEC Plan; if an OPSEC Plan is required, an agreement either to use an already approved OPSEC Plan or to draft a new OPSEC Plan; the consistency of OPSEC requirements among the various organizations and programs; OPSEC requirements in test control/conduct, including the use of "For Official Use Only" test cards and step calls and/or the use of secure communications.
  - -- Detailed planning and coordination will be required to ensure a common understanding of all requirements, procedures, test objectives, etc. since individual facilities are not generally familiar with conducting coordinated, distributed T&E tests. The communications, test control, OPSEC, and security aspects are different between standalone facility tests and a linked, integrated, weapon system test. Minutes and action items from meetings were not kept during the LSP and should be a part of any test/development effort. Maintaining and distributing minutes and action items will provide more structured and cohesive planning and coordination efforts which, in turn, should assist in resolving issues.

- SUT experts must be involved from the beginning . Weapon system(s) analysis experts must be planned for (and budgeted for) to analyze the weapon system-related data from the system under test (SUT) and to provide the analytical results, conclusions, and recommendations. There should be more than one expert, and they must be involved from the beginning of the project to establish the data and instrumentation requirements, verify/validate the analytical approach, assist in the development of test matrices and test procedures, and provide overall weapon system expertise. Options include the support and/or user agencies providing the SUT analysis experts. Both agencies could provide their own experts who would independently analyze the data from the standpoint of the test objectives. The independent analyses would then be compared, and the SUT experts would resolve any differences in their conclusions.

- Test communications requirements must be addressed early in the test planning phase
  - -- This is necessary to ensure effective communications during the test. Remote test control using two non-secure telephone conference bridges (i.e., two communications nets) was acceptable. However, the audio level between connections varied, making

"loud and clear" communications among all the sites difficult at times . This also caused the dynamic range of the recording media to be pushed to the limit. Additionally, the limit of two communications nets combined with the high ambient noise at the laboratories and the long distances between the telephone outlet(s) and the required location(s) for the handset/headset reduced the availability of communication options. For example, the F-14D pilot had to communicate with the WSIC operator via voice (i.e., shouting due to the distance between their locations), or by using two headsets (one for the control net and one for the internal WSIC net), or by talking on the control net which would have added extraneous and unnecessary communications on the control net.

-- A standard, linked test should have multiple (more than two) communications nets (e.g., control, analyst, network, and internal laboratory) with easy, selectable access to all the nets from multiple locations within the laboratory. A minimum of one secure telephone at each site is also required. More complex, linked tests may require additional non-secure and/or secure communications nets. Speakers with plug-in push-to-talk handsets and/or headsets with push-to-talk switches are required at strategic locations throughout the laboratory to allow individuals the necessary mobility and communications flexibility. Speakers are also necessary when VIP visitors or other personnel monitor the test at the laboratory. However, laboratories should not be required to duplicate full VIP "accommodations" that should already be set up at the test control center. Recommend laboratories research various communication options by reviewing their local range control center and telemetry data center communication setups.

-- The capability for secure video teleconferences (VTCs) among multiple (more than two) sites is required when planning, coordinating, and/or briefing integrated weapon system tests among various sites. This is currently a problem since NAWCWPNS only has the capability for a secure VTC between two sites. Additionally, secure telephone conference bridges are also required when a test must be conducted using secure communications (e.g., a special project test), or when a secure VTC is not available and secure briefs/debriefs are necessary.

5.2.1.2 Development

- A stepped buildup approach should be used

  -- Systematic checkout of the standalone simulators is needed before linking, especially verification of simulation laboratory modifications required for ADS linking. The modifications should be performed early in the buildup and carefully checked and verified before linked testing. The coordinate transformations needed for linked operation are a particular concern, and personnel who are subject matter experts in this area should be consulted during this process.

  -- Direct (non-DIS) links should be used during test buildup. This focuses early verification checks on making the linked architecture work without the additional interfaces and reference frame transformations needed for DIS implementation. This also provides a benchmark for the DIS implementation

-- Structured testing of the network must be performed prior to, and independent of, the linked testing times and the simulation laboratories to validate transmission/reception rates, bandwidth utilization, latency, data transmission and reception, etc. prior to commencing project test periods. A more in-depth and formal validation of each segment of the network in the test configuration is required prior to project operations. This includes a better understanding of the impact of each network device, including loggers, on the network, as well as any subnet and T1 issues, during test system operation. A "test, analyze, fix, test" approach in combination with structured, independent testing of the network during the LSP would have been beneficial. In several cases during the LSP, linked testing time was used for testing the network where independent network testing would have been more cost effective.

- Linking of facilities using ADS can require significant facility interface hardware and software development. ADS implementation is not "plug and play."

5.2.1.3 Execution

- Local (on-site) test monitoring/control should be used prior to remote test monitoring/ control. Numerous questions concerning test communications, test procedures, and general test coordination can be better addressed, and more quickly resolved, face-to-face. This process (local and then remote test monitoring/control) worked well during the LSP.

- Tight control of the aircrew is not desirable. The aircrew should be allowed to perform as aircrew during man-in-the-loop testing. Too much test control (e.g., "fire" instead of "cleared to fire") is not desirable with the man-in-the-loop, particularly if it is OT&E or combined DT&E/OT&E. Testing is more valuable and there are more "lessons learned" from a test where the aircrew are given the critical parameters and switchology to meet the test objective(s) and are still allowed to make tactical decisions, fly the "aircraft," operate the weapon system, etc. A tightly controlled test is appropriate for certain testing such as computer simulations and stand-alone laboratory tests.

- Additional time is needed before the beginning and after the end of each testing period. Allocate a minimum of an additional two hours of laboratory time at the end of each test period for data logging, data archiving, data transfer, and laboratory reclassification. Allocate a minimum of an additional one hour of laboratory set-up time prior to each test period. These were the normal pre- and post-test laboratory times required for each LSP formal test period. The pre- and post-test requirements should be included in the number of laboratory hours needed for each test period and incorporated into the planned costs.

- Briefings are needed before and after each mission. Briefs and debriefs should be conducted before and after each mission. The briefs should cover such items as the test objectives, telephone numbers/frequencies to use for test control, test configuration of each facility, instrumentation and data collection requirements, go/no go criteria, contingency/back-up plans, test conduct including a detailed review of test cards,

communications procedures, OPSEC, and the time and place of the debrief. A briefing checklist should be developed and used.

5.2.1.4 Evaluation

- Effective data management is needed. Linked laboratories can generate a large volume of data at distributed locations. Without careful planning, key data may not be collected and/or transmitted to the analysis center, and data collected at the sites may not be in a useful form for centralized analysis. A comprehensive data management plan must be developed before testing which clearly identifies (1) the data to be collected at each site, (2) on-site processing of the data, and (3) data to be transmitted to the analysis center.

- Adequate time must be allotted for data analysis between test events. There was a tendency to underestimate the time required to adequately analyze the large volume of data collected in the test events. As a result, some problems from one mission were not fully diagnosed and fixed before the next mission. In fact, some problems (e.g., target initialization errors) were not even recognized until all test was over. Rehearsal of the analysis procedures should be used to better estimate the time required for adequate analysis between test events.

- Tools for reading and analyzing raw simulation data should be ready for early verification testing. Verification of simulation performance, including proper inputs from other simulations, requires the ability to read and process the raw simulation data. Specialized tools are needed for this purpose.

5.2.2 Policy

- Future ADS T&E projects should be conducted following established T&E flight test practices and procedures. The LSP was more typical of a T&E flight test effort than a standard laboratory test. Specifically:
  - Standard Universal Documentation System (UDS) documents such as requirements documentation (e.g., Program Introduction (PI) and/or Operation Requirements (OR)) from the user agency and response documentation (e.g., Statement of Capability (SOC) and/or Operations Directive (OD)) from the support agency should be used. This would establish a clear set of requirements at the beginning of the program from the user agency and a clear statement of the support agency's capabilities, constraints, and limitations in meeting those requirements. A Statement of Capability was developed by NAWCWPNS (the support agency) for the LSP. High-level LSP functional requirements were outlined in the NAWCWPNS Integration Test Plan.
  - Test monitoring/control and test procedures/conduct should be run similar to a flight test. Detailed test cards should be drafted, reviewed, distributed, briefed, and used for each mission. Back-up test cards should also be considered and briefed for contingency purposes. Briefs and debriefs should be conducted before and after each mission. The briefs should cover such items as the test objectives; telephone numbers/frequencies to use for test control, etc.; test configuration of each laboratory;

instrumentation and data collection requirements; go/no go criteria; contingency/ back-up plans; test conduct including a detailed review of the test cards; communications procedures; OPSEC; and the time and place of the debrief. A briefing checklist should be developed and used. The LSP used one basic profile which permitted simplified test cards and test procedures. These simplified cards and procedures, including the use of a few "step" calls, were satisfactory for the LSP.

- Configuration control is essential. Configuration control of the network and the ADS/DIS system, including its hardware, software, and its simulator interfaces, is necessary starting at the beginning of the program. This includes a "scientific" approach to network management and troubleshooting. Either a single person or a network committee should be in charge of the configuration control/network management. The level of control will vary with the phase of the project. Since problems are part of the process, the network configuration cannot be "frozen" until there is an agreed upon "baseline." However, the configuration control process/procedures, individual/committee in charge, etc. must be established at the beginning of the program and followed until the end of the program.

5.2.3 Costs

- The LSP development effort should have been negotiated as a "cost" type contract with NAWCWPNS. The LSP program should not have been negotiated as a "firm fixed price" contract. Just like a user "buys" hours of range time, number of target presentations, specific instrumentation/data packages, etc., on a flight test program, so should a user "buy" hours of laboratory time, etc. for future ADS exercises, particularly those that test an integrated missile weapon/launch aircraft system.
  - A "firm fixed price" contract assumes all the requirements are completely and accurately specified at the beginning of the program. Since project requirements historically change over the course of a program, and assumptions have to be made concerning the specific details of the requirements during the initial planning/costing stage, it is difficult to accurately forecast total costs and hold to a "firm fixed price." As the requirements change, early assumptions are proved incorrect, and/or technical knowledge is gained on the program, as occurred during the LSP, and a "cost" type contract provides both the user and the support agencies with more flexibility. Information is readily available as to the costs which may be incurred if the user agency has to vary the number of missions, hours, etc. due to unforeseen circumstances and/or problems.
  - A "cost" type contract also reduces the potential for budget/funding disagreements during the course of the program. The user agency can more easily evaluate the options as things change during the project operations phase and then make the necessary trade-offs since the required cost information (e.g., the cost per hour for each laboratory) has already been provided.
  - A canceled/incompleted operations allowance should be budgeted for a linked laboratory test just as it is for a flight test. This allowance "plans" for missions that are canceled late, therefore incurring full or partial costs. It also "plans" for missions

where the test objectives are only partially accomplished and another mission is necessary to complete the test objectives.

5.2.4 Personnel

- DIS training early in the program was beneficial. The DIS class attended by the three primary NAWCWPNS engineers clarified DIS and unified their vision of what the DIS portion of the test would entail. ADS/DIS and other specialized training for the primary and supporting engineers should be planned, budgeted, and conducted very early in ADS program.

6.0 Conclusions/Recommendations

6.1 Utility

6.1.1 Utility Conclusions

- The LSP ADS configuration has utility for missile weapon/launch aircraft system T&E.
  - -- The configuration successfully ran inte grated scenarios/profiles among linked laboratories.
  - -- This configuration can be used for discrepancy/deficiency resolution, especially when there are interface issues/problems between/among weapon systems (e.g., the aircraft radar, mission computer, stores management system, and the missile). This includes troubleshooting problems which prove to be difficult to replicate, particularly those that appear in flight tests but are not readily duplicated in stand-alone laboratory testing.
  - -- Linked laboratorie s permit the HWIL missile to respond to actual pre- and post-launch weapon system inputs, instead of relying on stand-alone "canned" inputs, in a more operationally realistic environment

- The LSP ADS configuration has utility for parametric studies involving a one-on-one air-to-air missile engagement.
  - -- The key characteristic of a parametric study is the ability to repeat a given scenario with either no changes or with a single parameter varying.
  - -- The manual method for replicating a given profile resul ted in very good run-to-run reproducibility of the launch conditions.
  - -- The automatic replay method, as implemented in the LSP, was unable to precisely replicate a given scenario and had no advantage over the manual method.

- The LSP ADS configuration has utility for rehearsal and refinement of live engagement scenarios.
  - -- Pilot training and rehearsals of live missile firings requiring difficult and/or precise launch conditions could be accomplished using this configuration. The ADS link could be used by the pilot to practice (pre-fly) the mission in a controlled laboratory environment before using aircraft and range assets. ADS could assist in doing the flight test right the first time which translates into reduced aircraft flight hours, range time, etc.

- The LSP ADS configuration does not have utility for OT&E, tactics development, and "free play" scenarios.
  - -- The aircraft weapon system laboratories did not have totally realistic flying/handling qualities when compared to the actual aircraft or sophisticated visual presentation systems; they were primarily designed for stand-alone weapon system testing.
  - -- The missile HWIL laboratory could not handle large angles off and/or large angle rates to accommodate the above scenarios.

- The LSP ADS configuration does not have utility for terminal engagement studies involving closed-loop interactions between the missile and the target.
  -- Target position errors and latencies were such that the nodes disagreed on the final range between the missile and the target by more than the missile lethal radius. Hence, the nodes could disagree on whether or not the target had been "killed."

6.1.2 Utility Recommendations

- Develop a flight test data playback capability for the laboratories which can also be precisely controlled/coordinated between/among laboratories.
  -- Aircraft weapon system and missile system laboratories should have the capability to replay flight test data (i.e., weapon system, missile, sensor, mission computer, TSPI, etc.) as a method to "drive" the flight profile of the laboratory and/or its high fidelity simulation.
  -- There should also be options for user- selectable full or partial/subset replay of the data. For example, the user may only be interested in replaying the SMS data on the avionics bus without having to replay all the data from all the buses.
  -- Additionally, automated control (e.g., using the simulation management PDUs) is required when attempting to exactly replicate/replay a specific profile, set of parameters, or series of events.

- The LSP utility can be extended to OT&E, tactics development, and "free play" scenarios by linking more realistic aircraft and missile HWIL laboratories which are able to accommodate these scenarios.

6.2 Technical

6.2.1 Technical Conclusions

- The LSP test objectives were successfully accomplished.
  -- The V&V method implemented identified errors in interfacing the target and shooter entity state data to the missile HWIL simulation.
  -- The LSP ADS configuration was shown to have utility for parametric studies involving an air-to-air missile engagement with IRCM.
  -- The latency of the LSP ADS configuration was evaluated and determined to be sufficiently small such that the shooter and target entities could agree on launch conditions to within 10% of the shot box.
  -- The LSP ADS configuration was assessed as being able to support AIM-9 testing, with the exception of closely-coupled terminal engagements between the missile and the target.

- The sample-to-sample variations in latency during a run represent a fundamental limitation to low-latency applications. The standard deviations of the latencies were typically significant fractions of the mean values (~35%-60%). These random latency variations

cannot be eliminated by deterministic corrections and resulted in an uncertainty in the target position as observed at the SIMLAB on the order of 30 ft.

- Future ADS applications for evaluation of closely-coupled terminal engagements between the missile and target will require special design to achieve sufficient simulation synchronization and low latencies. The simulation computers must have their frame rates synchronized and latencies must be reduced to less than the frame time. This degree of synchronization will require modifications to the simulation computers themselves, or else ADS must be designed into the simulation computers from the start.

6.2.2 Technical Recommendations

- Future ADS applications for missile T&E should use an improved NIU or an "NIU function" (in the master simulation computer). The objective would be to provide a more direct user control of the content of the data and network communications, including the capability to force network communications at a user-specified frame rate. Such improvements could simplify the overall network/ADS configuration, as well as the troubleshooting and resolution of various network/ADS/DIS problems.

6.3 Infrastructure

6.3.1 Infrastructure Conclusions

- While this was a relatively simple architecture, the set-up and checkout activities consumed significantly more time than planned. A dwindling number of people have an expectation that creating a linked T&E architecture is a "plug-and-play" exercise. This test phase clearly showed it is not.

- A sequential, build-up approach to verifying network performance is necessary. Initially, a lot of attention needs to be paid to the simulators and simulations in a standalone mode so that network-driven modifications can be checked out. Only when each node has been judged "healthy" does it make sense to embark upon the assessment of the integrated architecture.

- A full-up linked architecture is necessary to validate "fixes." Many fixes cannot be adequately assessed unless the entire network is used. Test planners should incorporate these linked tesing periods in their schedules and budgets --- they are not any cheaper than rehearsals.

- Test planners engaged in using this kind of architecture should probably plan for two attempts on every required mission. (Bear in mind this test only had three participating nodes, and a control node --- as the number of nodes goes up, the planner's expectations should go down.) Additional time prior to the start of test, and at the end of each test period is necessary. The former to fine tune the network, and eliminate start-up glitches, and the latter to accommodate data logging, archiving, and transfer.

- Test control worked well, whether implemented from the BMIC or the TCAC. In a distributed test architecture, the control mechanism must support a sensible blend of centralization, test direction, level of control, and decentralization, test execution, node-level controls. The emergencies usually occur at the node level; adjustments after emergencies are usually best managed at the test direction level.

- Configuration control, and the associated documentation, is essential to a successful test program. An adequate management structure, with the requisite authority, must be put in place prior to the start of testing.

- The SUT experts must be invo lved very early in the network architecture design process. The elements of the network interact, sometimes in subtle ways, with the systems and subsystems of the SUT.

6.3.2 Infrastructure Recommendations

- Future ADS T&E projects should be conducted following established T&E flight test practices and procedures. This is especially important when linking laboratories which are not usually involved in T&E.

- Future ADS development efforts should be negotiated with the range/test facilities as "cost" type contracts, rather than "firm fixed price" contracts.

APPENDIX A

CLASSIFIED SUPPLEMENT

for the

SYSTEM INTEGRATION TEST

LINKED SIMULATORS PHASE

(AVAILABLE UNDER SEPARATE COVER FROM JADS JTF)

APPENDIX B

SECURITY

for the

SYSTEM INTEGRATION TEST

LINKED SIMULATORS PHASE

MEMORANDUM OF AGREEMENT
AMONG THE USERS OF THE
NAWCWPNS REALTIME NETWORK
(NRNet)

1.0 INTRODUCTION:

The Naval Air Warfare Center Weapons Division (NAWCWPNS) Realtime Network (NRNet) is a secured network capable of transporting up to and including SECRET information. NRNet contains point-to-point T-Carrier communications links covered by National Security Agency approved cryptographic equipment (KG-194, KIV-7, etc.). NRNet is a high capacity network supporting a full spectrum of warfighting test and evaluation, training, and simulation interoperability activities. This Memorandum of Agreement (MOA) contains the requirements for interconnection and secure operation of user systems connected to the NRNet.

2.0 RULES FOR CONNECTION AND SECURE OPERATION OF THE NRNet:

Each NRNet User System Designated Approving Authority (DAA) must agree to this MOA and take responsibility for ensuring proper secure operation by signing this agreement. All NRNet User Systems must meet the rules for connection and ensure secure operation on the NRNet. The NRNet DAA will adjudicate accreditation differences between each NRNet User System DAA. Because of the multiservice/agency nature of the NRNet, each User System is accredited for the dedicated Mode of Operation at the SECRET security level under the provisions of DoD Directive 5200.28, Security Requirements for Automated Information Systems (AIS).

The boundary of the NRNet is defined to be the unencrypted/clear Ethernet interface at each NRNet Router. The NRNet DAA has security responsibility from that interface through the NRNet while the User System DAA has security responsibility from that interface back into the User's System. The User System DAA has responsibility to ensure that all AIS connected in any way to the NRNet meet the rules for connection and secure operation of the NRNet.

As a minimum AIS Security requirement, all AIS must at least meet DoD 5200.28 requirements for the dedicated Mode of Operation SECRET security level. The accreditation letter/document for the USER System will be provided by the User System DAA and will become part of this MOA.

If the User System covered in this MOA provides connection to an AIS not managed by the User System DAA, the DAA for the User System will establish an MOA with connecting AIS DAA in accordance with the requirements of DoD Directive 5200.28, that ensures continued compliance with the rules for connection and secure operation of the NRNet

User Systems must meet all installation, physical protection, accounting, procedural and access control protection mechanisms required for SECRET operation of the NRNet and the accredited AIS at their site.

Every User System agrees to operate the NRNet in accordance with the doctrine provided by the National Security Agency (NSA) andNRNet Management.

User Systems must have Communication Security (COMSEC) Material System (CMS) accounts and must use NRNet Administrator approved NSA provided keying material for NRNet managed cryptographic devices.

User Systems may be untrusted systems operating in the dedicated mode at the SECRET (NOFORN) security level. This is expected to be the normal Mode of Operation for every AIS connected to the NRNet. In this mode of operation, all users must have the appropriate clearance and need-to-know for all data handled by their AIS. Additionally, the User System DAA acknowledges that all users of the NRNet may have access to the data contained within their accredited AIS.

User Systems may be untrusted systems, operating in the system high SECRET security level. User Systems accredited to operate in this mode, which connect to the NRNet, acknowledge that the NRNet provides no protection within the NRNet or other user systems beyond those of DoD Directive 5200.28 accredited dedicated level mode of operation. User Systems accredited to operate in the system high SECRET security level mode accept responsibility for the possibility of increased risk to their AIS because of the interconnection with systems accredited to operate in the dedicated Mode of Operation.

User Systems may connect with a single security level of SECRET, labeled port on a trusted AIS accredited to operate in the multilevel mode with the risk range identified in the DoD Directive 5200.28. User Systems accredited to operate in this mode, which connect to the NRNet, acknowledge that the NRNet provides no protection within it's network or other User Systems beyond those of DoD Directive 5200.28 dedicated Mode of Operation. User Systems accredited to operate in the multilevel mode accept responsibility for the possibility of increased risk to the AIS because of the interconnection with systems accredited to operate in the dedicated mode.

User Systems that employ trusted operating systems must operate the systems in accordance with the systems' Security Features Users Guide and the Trusted Facility Manual.

User Systems must treat all data or information via the NRNet Ports as classified at the SECRET level until the data or information has been manually reviewed and downgraded. Permanent storage media for data or information will be labeled and controlled at the SECRET level.

Each User System must identify its facility accreditation authority and provide evidence of site accreditation at the SECRET level before connection to theNRNet.

3.0 USER SYSTEMS SPECIFIC INFORMATION:

3.1 Name of POC and AIS Component Connected to the NRNet:

3.1.1 Naval Air Warfare Center Weapons Division
Sea Range - Communications Building
Building 531, Point Mugu, CA 93042
AIS System Security Officer: Joel Bossoletti
Code 524300E
DSN 351-0902
Com (805) 989-0902

3.1.2 Naval Air Warfare Center Weapons Division
F-14D Weapons Support Integration Capability (WSIC)
Building 761, Point Mugu, CA 93042
AIS System Security Officer: Brian Krinsley
Code 41L200E
DSN 351-9007
Com (805) 989-9007

3.1.3 Naval Air Warfare Center Weapons Division
Land Range - Range Control Center
Building 31455, China Lake, CA 93555-6001
AIS System Security Officer: Bob Eisenhauer
Code 524500D
DSN 437-6717
Com (619) 939-6717

3.1.4 Naval Air Warfare Center Weapons Division
F/A-18 Weapons Systems Support Facility (WSSF)
Building 20279, China Lake, CA 93555-6001
AIS System Security Officer: Wray Jacobs
Code 413100D
DSN 437-5106
Com (619) 939-5106

3.1.5 Naval Air Warfare Center Weapons Division
Simulation Laboratory (SIMLAB)
Building 00005, China Lake, CA 93555-6001
AIS System Security Officer: Ed Slack
Code 471700D
DSN 437-1457
Com (619) 939-1457

3.1.6 Naval Air Warfare Center Weapons Division
Weapons Tactics (WEPTAC)
Building 03264, China Lake, CA 93555-6001
AIS System Security Officer: Mark Hilde
Code 4J5100D
DSN 469-1929
Com (619) 927-1929

3.1.7 US Air Force
TCAC
1951 2nd Street SE
Kirtland AFB, NM 87117-5617
AIS System Security Officer: Lt Col Homer L. Jeffers, USAF
Code JADS JTF
DSN 246-0528
Com (505) 846-0528

3.2 Highest Classification of Data or Information processed on theAIS:

US SECRET

3.3 Approval Date:

15 April 1996

3.4 Accredited Operation Mode:

SYSTEM HIGH SECRET (NOFORN)

4.0 USER SYSTEM CERTIFICATION:

As the DAA for my NRNet System, I hereby certify that the area that houses my NRNet Nodes(s) has a facility accreditation approval for the operation at SYSTEM HIGH SECRET, while connected to NRNet. I further certify that the proper policies and procedures are in place to ensure that the AIS/NRNet equipment at my site will be operated in a manner that meets the NSA Doctrine for the encryption equipment used and

the DoD Directive 5200.28 requirements for SECRET (NOFORN) security level in the system high mode.

I concur with this Memorandum of Agreement

Date: ___________

4.1 Name: RADM Dana B. McKinney, USN

Title: Designated Approving Authority
Naval Air Warfare Center Weapons Division

Signature: ___________________________

4.2 Name: Lt Col Homer L. Jeffers, USAF

Title: Designated Approving Authority
JADS JTF

Signature: ___________________________

APPENDIX C

INTEGRATED DATA REQUIREMENTS LIST

for the

SYSTEM INTEGRATION TEST

LINKED SIMULATORS PHASE

LIST OF TABLES

Table C-1. General Test Parameters

Data Requirement	Description	Units	Frequency
Test Name	Linked Simulators Phase	N/A	Once
Mission Number	Mission identification number from TAP	N/A	Each mission
Profile Number	Profile identification number from TAP	N/A	Each profile
Trial Number	Trial identification number from test sequence	N/A	Each trial
Trial Date	Date of trial	DD-MM-YY	Each trial
Trial Start Time	Time at TCAC when start trial command issued	HH:MM:SS.SSS	Each trial
Trial Hold Time	Time at TCAC when hold trial command issued	HH:MM:SS.SSS	Each hold, if applicable
Trial Restart Time	Time at TCAC when restart trial command issued	HH:MM:SS.SSS	Each restart, if applicable
Trial Stop Time	Time at TCAC when stop trial command issued	HH:MM:SS.SSS	Each trial
Trial Problems	Any problem encountered in executing trial. Reason for trial hold.	N/A	Each trial/hold, if applicable

Table C-2. Parameters Recorded at F/A-18 WSSF

Data Requirement	Description	Units	Frequency
Shooter entity state data	WSSF sim computer output for shooter		Each trial
Time	UTC time in IRIG-B format		Every 50 ms
Latitude		Radians	Every 50 ms
Longitude		Radians	Every 50 ms
Altitude		Feet	Every 50 ms
Heading, True		Radians	Every 50 ms
Pitch & Roll		Radians	Every 50 ms
Pitch, Roll, & Yaw Rates		Radians/Sec	Every 50 ms
Velocities (NED)		Feet/Sec	Every 50 ms
Accelerations (NED)		Feet/Sec^2	Every 50 ms
Entity ID		Numeric	Every 50 ms
Target entity state data	Logged by WSSF sim from WSIC		Each trial
Time	UTC time in IRIG-B format		Every 50 ms
Latitude		Radians	Every 50 ms
Longitude		Radians	Every 50 ms
Altitude		Feet	Every 50 ms
Heading, True		Radians	Every 50 ms
Pitch & Roll		Radians	Every 50 ms
Pitch, Roll, & Yaw Rates		Radians/Sec	Every 50 ms
Velocities (NED)		Feet/Sec	Every 50 ms
Accelerations (NED)		Feet/Sec^2	Every 50 ms
Entity ID		Numeric	Every 50 ms
Missile entity state data	Logged by WSSF sim from SIMLAB		Each trial
Time	UTC time in IRIG-B format		Every 50 ms
Latitude		Radians	Every 50 ms
Longitude		Radians	Every 50 ms
Altitude		Feet	Every 50 ms
Heading, True		Radians	Every 50 ms
Pitch & Roll		Radians	Every 50 ms
Pitch, Roll, & Yaw Rates		Radians/Sec	Every 50 ms
Velocities (NED)		Feet/Sec	Every 50 ms
Accelerations (NED)		Feet/Sec^2	Every 50 ms
Entity ID		Numeric	Every 50 ms

Table C-2. Parameters Recorded at F/A-18 WSSF (Concluded)

Data Requirement	Description	Units	Frequency
PDU Data	Logged on WSSF STRICOM Logger		
Shooter entity state PDU	Generated by WSSF, see Table C1-1		Each trial, when sent
Target entity state PDU	Received at WSSF from WSIC, see Table C1-2		Each trial, upon receipt
Missile entity state PDU	Received at WSSF from SIMLAB, see Table C1-3		Each trial, upon receipt
Fire (flare) PDU	Received at WSSF from WSIC, see Table C1-4		Each trial, once
Fire (missile) PDU	Received at WSSF from SIMLAB, see Table C1-5		Each trial, once
Detonation PDU	Received at WSSF from SIMLAB, see Table C1-6		Each trial, once

Table C-3. Parameters Recorded at F-14D WSIC

Data Requirement	Description	Units	Frequency
Target entity state data	WSIC sim computer output for target		Each trial
Time	UTC time in IRIG-B format		Every 25 ms
Latitude		Degrees, Minutes	Every 25 ms
Longitude		Degrees, Minutes	Every 25 ms
Altitude		Feet	Every 25 ms
Heading, True	WSIC only data	Degrees	Every 25 ms
Pitch, Roll		Degrees	Every 25 ms
Yaw	From NIU recording only	Degrees	Every 25 ms
Pitch, Roll, & Yaw Rates		Degrees/Sec	Every 25 ms
Velocities (NED)		Feet/Sec	Every 25 ms
Accelerations (NED)		Feet/Sec^2	Every 25 ms
Entity ID	From NIU recording only	Numeric	Every 25 ms
PDU Data	Logged on WSIC STRICOM Logger		
Target entity state PDU	Generated by WSIC, see Table C1-2		Each trial, when sent
Fire (flare) PDU	Generated by WSIC, see Table C1-4		Each trial, once
Shooter entity state PDU	Received at WSIC from WSSF, see Table C1-1		Each trial, upon receipt
Missile entity state PDU	Received at WSIC from SIMLAB, see Table C1-3		Each trial, upon receipt
Fire (missile) PDU	Received at WSIC from SIMLAB, see Table C1-5		Each trial, once
Detonation PDU	Received at WSIC from SIMLAB, see Table C1-6		Each trial, once

Table C-4. Parameters Recorded at AIM-9M SIMLAB

Data Requirement	Description	Units	Frequency
Simulation and Facility Data	Internal SIMLAB simulation parameters		Each trial
SYSTEM_TIME	Simulation Time from Start of Missile Flyout	Sec	Every 50 ms
IRIG_TIME	IRIG-B Time		Every 50 ms
DELTA_RL	Canard Angle (R/L)	Degrees	Every 50 ms
DELTA_UD	Canard Angle (U/D)	Degrees	Every 50 ms
PHIDOT_AZ	Azimuth Seeker Precession Rate	Degrees/Sec	Every 50 ms
PHIDOT_EL	Elevation Seeker Precession Rate	Degrees/Sec	Every 50 ms
CSA_RL	Servo Amp Output (R/L)	ma	Every 50 ms
CSA_UD	Servo Amp Output (U/D)	ma	Every 50 ms
COMMAND_RL_HDW	Seeker Hardware Unscaled Guidance Command (R/L)		Every 50 ms
COMMAND_UD_HDW	Seeker Hardware Unscaled Guidance Command (U/D)		Every 50 ms
LAMBDA_AZ	Azimuth Seeker Gimbal Angle	Degrees	Every 50 ms
LAMBDA_EL	Elevation Seeker Gimbal Angle	Degrees	Every 50 ms
PHIW	Aero Roll Angle	Radians	Every 50 ms
PHI	Missile Roll Euler Angle	Radians	Every 50 ms
THETA_CARCO	Pitch Carco Command	Degrees/Sec	Every 50 ms
THETA_CT_FB	Carco Table Pitch Feedback	Degrees	Every 50 ms
THETA_ERR	Difference between Carco Pitch Command and Feedback	Degrees	Every 50 ms
PHI_CT	Commanded Carco Roll Position	Degrees	Every 50 ms
PHI_CT_FB	Carco Roll Position Feedback	Degrees	Every 50 ms
PSI_CARCO	Azimuth Carco Command	Degrees/Sec	Every 50 ms
PSI_CT_FB	Carco Table Yaw Feedback	Degrees	Every 50 ms
PSI_ERR	Difference between Carco Yaw Command and Feedback	Degrees	Every 50 ms
MIRROR_AZ_CMD	Voltage Command to Azimuth Mirror	Volts	Every 50 ms
MIR_AZ_FB	Feedback from Azimuth Mirror	Degrees	Every 50 ms
MIRROR_EL_CMD	Voltage Command to Elevation Mirror	Volts	Every 50 ms
MIR_EL_FB	Feedback from Elevation Mirror	Degrees	Every 50 ms
TRANS_CMD	Normalized, Limited Command to the Mirror Translation Axis		Every 50 ms
MIR_TRANS_FB	Feedback from Mirror Translation	Inches	Every 50 ms
FLARE_FLAG	Flag Output by Flare Simulator Indicating Flare Release		Every 50 ms

Table C-4. Parameters Recorded at AIM-9M SIMLAB (Cont'd)

Data Requirement	Description	Units	Frequency
Missile Entity State Data	SIMLAB sim computer output for missile		Every trial
XM	Missile Position Along InertialX-Axis	Feet	Every 50 ms
YM	Missile Position Along InertialY-Axis	Feet	Every 50 ms
ZM	Missile Position Along InertialZ-Axis	Feet	Every 50 ms
XMD	Missile Velocity Along InertialX-Axis	Feet/Sec	Every 50 ms
YMD	Missile Velocity Along InertialY-Axis	Feet/Sec	Every 50 ms
ZMD	Missile Velocity Along InertialZ-Axis	Feet/Sec	Every 50 ms
AX_G	Missile Accel Along Inertial X-Axis	g's	Every 50 ms
AY_G	Missile Accel Along Inertial Y-Axis	g's	Every 50 ms
AZ_G	Missile Accel Along Inertial Z-Axis	g's	Every 50 ms
RANGE	Distance between Missile and Target	Feet	Every 50 ms
VELOCITY	Total Missile Velocity	Feet/Sec	Every 50 ms
MACH	Missile Mach Number		Every 50 ms
BETA	Missile Sideslip Angle of Attack	Degrees	Every 50 ms
ALPHA	Missile Pitch Angle of Attack	Degrees	Every 50 ms
R	Missile Inertial Yaw Rate	Radians/Sec	Every 50 ms
Q	Missile Inertial Pitch Rate	Radians/Sec	Every 50 ms
P	Missile Inertial Roll Rate	Radians/Sec	Every 50 ms
WSSF_MS_LAT	Missile Latitude	Radians	Every 50 ms
WSSF_MS_LON	Missile Longitude	Radians	Every 50 ms
WSSF_MS_HDG	Missile Heading, Shooter/ Target Earth Frame	Radians	Every 50 ms
WSSF_MS_VN	Missile North Velocity Component, Shooter/ Target Earth Frame	Feet/Sec	Every 50 ms
WSSF_MS_VE	Missile East Velocity Component, Shooter/ Target Earth Frame	Feet/Sec	Every 50 ms
WSSF_MS_VD	Missile Down Velocity Component, Shooter/ Target Earth Frame	Feet/Sec	Every 50 ms
Entity ID		Numeric	Every 50 ms
Seeker TM Signals	Signals from Seeker Hardware		Every trial
Rate Bias			Every 50 ms
Lambda Comp			Every 50 ms
AGC Overshoot			Every 50 ms
AGC Control			Every 50 ms
Solenoid Comm U/D			Every 50 ms
Solenoid Comm R/L			Every 50 ms
AGC Audio			Every 50 ms
Lambda			Every 50 ms
Ratio Detect			Every 50 ms

Table C-4. Parameters Recorded at AIM-9M SIMLAB (Cont'd)

Data Requirement	Description	Units	Frequency
Target Entity State Output Data	SIMLAB sim computer output for target		Every trial
XT	Target Position Along Inertial X-Axis	Feet	Every 50 ms
YT	Target Position Along Inertial Y-Axis	Feet	Every 50 ms
ZT	Target Position Along Inertial Z-Axis	Feet	Every 50 ms
XT_DOT	Target Velocity Along Inertial X-Axis	Feet/Sec	Every 50 ms
YT_DOT	Target Velocity Along Inertial Y-Axis	Feet/Sec	Every 50 ms
ZT_DOT	Target Velocity Along Inertial Z-Axis	Feet/Sec	Every 50 ms
VEL_TG	Total Target Velocity	Feet/Sec	Every 50 ms
WSSF_TGP_LAT	Target Latitude From Conversion of Inertial Coordinates	Radians	Every 50 ms
WSSF_TGP_LON	Target Longitude From Conversion of Inertial Coordinates	Radians	Every 50 ms
TLAT_P	Target Latitude From Integration of Target North Velocity	Feet/Sec	Every 50 ms
TLON_P	Target Longitude From Integration of Target East Velocity	Feet/Sec	Every 50 ms
Target Entity State Input Data	Logged by SIMLAB sim from WSIC		Every trial
WSSF_TG_LAT	Target Latitude	Radians	Every 50 ms
WSSF_TG_LON	Target Longitude	Radians	Every 50 ms
WSSF_TG_ALT	Target Altitude	Feet	Every 50 ms
WSSF_TG_PIT	Target Pitch Euler Angle, Shooter/ Target Earth Frame	Radians	Every 50 ms
WSSF_TG_ROL	Target Roll Euler Angle, Shooter/ Target Earth Frame	Radians	Every 50 ms
WSSF_TG_HDG	Target Heading, Shooter/ Target Earth Frame	Radians	Every 50 ms
WSSF_TG_VN	Target North Velocity Component, Shooter/ Target Earth Frame	Feet/Sec	Every 50 ms
WSSF_TG_VE	Target East Velocity Component, Shooter/ Target Earth Frame	Feet/Sec	Every 50 ms
WSSF_TG_VD	Target Down Velocity Component, Shooter/ Target Earth Frame	Feet/Sec	Every 50 ms

Table C-4. Parameters Recorded at AIM-9M SIMLAB (Concluded)

Data Requirement	Description	Units	Frequency
Launch Conditions	Determined by SIMLAB simulation		
RANGE0	Initial Distance between Missile and Target	Feet	Each trial, once
SIGMA_AZ0	Initial Target Aspect Angle	Degrees	Each trial, once
SIGMA_EL0	Initial LOS Elevation Angle	Degrees	Each trial, once
ALT_L	Missile Launch Altitude	Feet	Each trial, once
VEL_L	Missile Launch Velocity	Feet/Sec	Each trial, once
ZLEAD	Initial Lead Angle	Degrees	Each trial, once
ALT_T	Initial Target Altitude	Feet	Each trial, once
VEL_T	Initial Target Velocity	Feet/Sec	Each trial, once
FLARE TIME	Time of flare sim start relative to launch	Sec	Each trial, once
INITIAL RANGE RATE	Rate range between missile and target is decreasing at launch	Feet/Sec	Each trial, once
Final Conditions	Determined by SIMLAB simulation		
Projected Miss Distance (Horizontal)	Horizontal distance of closest approach between missile and target extrapolated from end of simulation	Feet	Each trial, once
Projected Miss Distance (Vertical)	Vertical distance of closest approach between missile and target extrapolated from end of sim	Feet	Each trial, once
TIME OF FLIGHT	Duration of missile flight at end ofsim	Sec	Each trial, once
TIME_TO_GO	Remaining time aftersim stops until missile reaches miss distance	Sec	Each trial, once
FINAL RANGE	Distance between missile and target at end of sim	Feet	Each trial, once
FINAL RANGE RATE	Rate range between missile and target is decreasing at end of sim	Feet/Sec	Each trial, once
PDU Data	Logged on SIMLAB STRICOM Logger		
Missile entity state PDU	Generated by SIMLAB, see Table B1-3		Each trial, when sent
Fire (missile) PDU	Generated by SIMLAB, see Table B1-5		Each trial, once
Detonation PDU	Generated by SIMLAB, see Table B1-6		Each trial, once
Target entity state PDU	Received at SIMLAB from WSIC, see Table B1-2		Each trial, upon receipt
Fire (flare) PDU	Received at SIMLAB from WSIC, see Table B1-4		Each trial, once
Shooter entity state PDU	Received at SIMLAB from WSSF, see Table B1-1		Each trial, upon receipt

Table C-5. Parameters Recorded at TCAC

Data Requirement	Description	Units	Frequency
PDU Data	Logged on TCAC STRICOM Logger		
Shooter entity state PDU	Received at TCAC from WSSF, see Table B1-1		Each trial, upon receipt
Target entity state PDU	Received at TCAC from WSIC, see Table B1-2		Each trial, upon receipt
Missile entity state PDU	Received at TCAC from SIMLAB, see Table B1-3		Each trial, upon receipt
Fire (flare) PDU	Received at TCAC from WSIC, see Table B1-4		Each trial, once
Fire (missile) PDU	Received at TCAC from SIMLAB, see Table B1-5		Each trial, once
Detonation PDU	Received at TCAC from SIMLAB, see Table B1-6		Each trial, once
Data PDU[1]	Received at TCAC from Pt. Mugu, used to drive test control displays		Each trial, upon receipt

Note: (1) The following test control display parameters were contained in the Data PDU:
- Shooter Altitude (ft)
- Shooter Mach Number
- Target Altitude (ft)
- Target Mach Number
- Target Acceleration (g's)
- Closing Speed Between Shooter and Target (knots)
- Data Needed to Determine Target Aspect Angle (degrees)
- Shooter Radar Azimuth and Elevation (degrees)
- Range Between Shooter and Target (ft)
- Radar Mode Discrete
- Master Arm Discrete
- Trigger Discrete

ANNEX 1

PDU DESCRIPTIONS

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PDU DESCRIPTIONS

C1.1.0 General Specifications: The following specifications apply to all PDU tables in this annex unless otherwise noted.

C1.1.1 PDU Data Types - Data types are designated as follows:

E = Enumeration
UI = Unsigned Integer
SI = Signed Integer
FP = Floating Point Number
DPFP = Double Precision Floating Point Number
Bool = Boolian Field
(na) = not applicable

C1.1.2 Enumeration Representation - All enumerated types shall begin with "zero" for the first element of the enumeration. Enumerations may have any size between 1 and 32 bits. Zero shall mean "other".

C1.1.3 Number Representation - Numbers shall be represented as either floating point numbers or integers.

C1.1.3.1 Floating Point Numbers: Single and double precision floating point numbers shall adhere to the IEEE 754-1985 Standard.

C1.1.3.2 Integers: Integers shall be represented as signed or unsigned. **Signed Integers** shall be represented in **2's-complement form** where the **most significant bit** shall designate the **sign bit**. This bit shall have a value of **"0" for positive numbers** and **"1" for negative numbers**. Integers may have a size of 8, 16, or 32 bits.

C1.1.4 Coordinate Systems

C1.1.4.1 World Coordinates - The shape of the world is described by the WGS-84 standard, DMA TR 8350.2. The world coordinate system is a right-handed, geocentric Cartesian system (see Figure C1-1). The origin is the centroid of the earth; the positive X-axis passes through the prime meridian at the equator; the positive Y-axis passes through 90 degrees East longitude at the Equator; the positive Z-axis passes through the North pole.

C1.1.4.2 Entity Coordinates - The entity coordinate system is a right-handed Cartesian coordinate system (see Figure C1-2). The origin is at the center of the entity's bounding volume (excluding articulated or attached parts); the positive X-axis is toward the front; the positive Y-axis is to the right side; the positive Z-axis is out the bottom.

C1.1.4.3 Location of Entity - Defined as the location of the origin-of-entity in World Coordinates.

C1.1.4.4 Orientation of Entity - Defined as three angles describing the succession of rotations needed to transform from World Coordinate system to entity's coordinate system. The order of rotation is: (1) Rotate about Z by angle psi, (2) rotate about the new Y by angle theta, (3) rotate about newest X by the angle phi. See Figures C1-3a thru C1-3c.

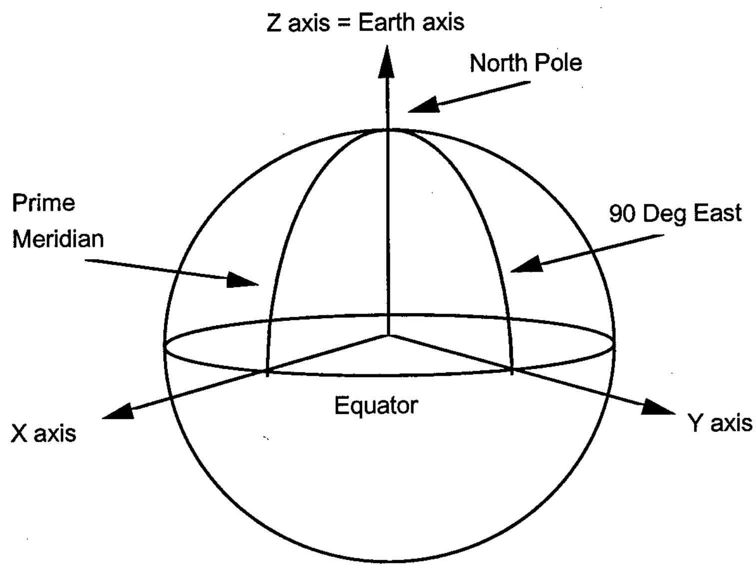


Figure C1-1. World Coordinate System

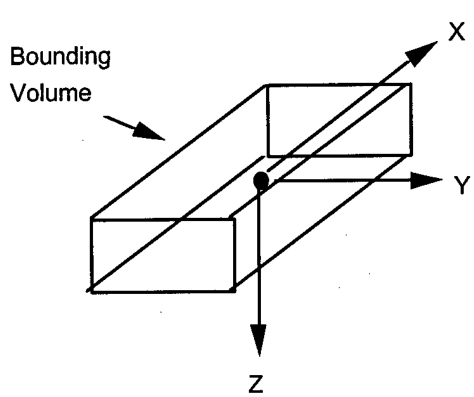


Figure C1-2. Entity Coordinate System

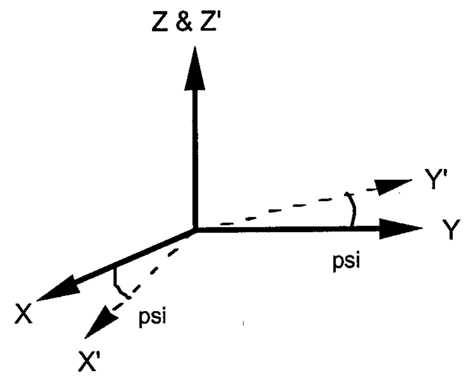


Figure C1-3a. First Rotate About Z-Axis By Psi

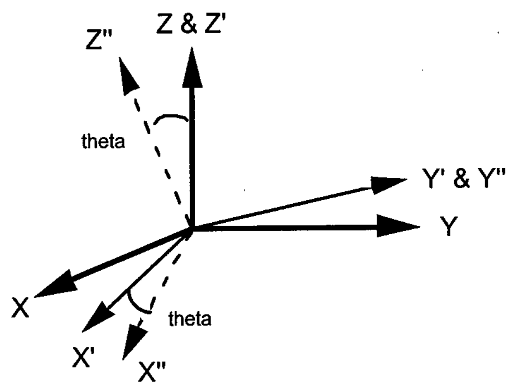


Figure C1-3b. Second Rotate About Y'-Axis By Theta

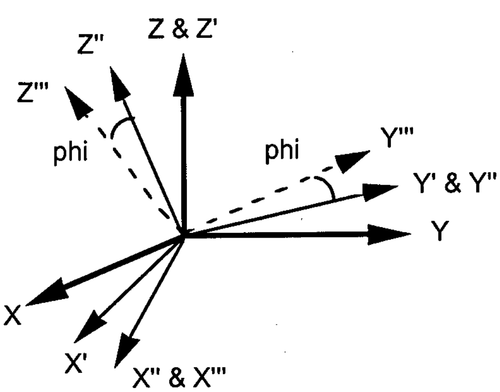


Figure C1-3c. Third Rotate About X"-Axis By Phi

Figure C1-3. Definition of Entity Orientation

Table C1-1. Shooter Entity State PDU

Field Size (Bits)	Category	No. Bits	Function	PDU Data		
				Units	Enum	Enumeration Meaning
96	PDU Header	8	Protocol Version	-	4	DIS Ver 2.0.4
		8	Exercise ID	-	1	JADS LSP
		8	PDU Type	-	1	Entity State
		8	Protocol Family	-	1	Entity Info/Inter
		32	Time Stamp (1)	sec	-	
		16	Length	octects	144	PDU=144 octets
		16	Padding	dim	-	-
48	Entity ID	16	Site	-	1	WSSF
		16	Application	-	1	F-18 Simul
		16	Entity	-	1	Shooter
8	Force ID	8		-	1	Friendly
8	# Artic. Param	8		-	0	(none)
64	Entity Type	8	Entity Kind	-	1	Platform
		8	Domain	-	2	Air
		16	Country	-	225	United States
		8	Category	-	1	Ftr/Air Defense
		8	Subcategory	-	9	F/A-18 Hornet
		8	Specific	-	1	F/A-18A
		8	Extra	-	0	(other)
64	Alternative Entity Type	8	Entity Kind	-	1	Platform
		8	Domain	-	2	Air
		16	Country	-	225	United States
		8	Category	-	1	Ftr/Air Defense
		8	Subcategory	-	9	F-14 Tomcat
		8	Specific	-	0	(other)
		8	Extra	-	0	(other)
96	Entity Linear Velocity	32	X	m/sec	-	-
		32	Y	m/sec	-	-
		32	Z	m/sec	-	-
192	Entity Location	64	X (WGS84 world coord)	meters	-	-
		64	Y (WGS84 world coord)	meters	-	-
		64	Z (WGS84 world coord)	meters	-	-
96	Entity Orientation	32	Psi (Euler angle)	rad	-	-
		32	Theta (Euler angle)	rad	-	-
		32	Phi (Euler angle)	rad	-	-
32	Entity Appear	32		-	0	No appearance

Table C1-1. Shooter Entity State PDU (Concluded)

Field Size (Bits)	Category	No. Bits	Function	PDU Data Units	Enum	Enumeration Meaning
320	Dead Reckoning Parameters	8	Dead Reck. Algor.	-	2	DRM(F,P,W)
		120	(Other - unused)	-	-	
		32	Ent Linear Accel - X	m/sec^2	-	-
		32	Ent Linear Accel - Y	m/sec^2	-	-
		32	Ent Linear Accel - Z	m/sec^2	-	-
		32	Ent Angular Vel.	rad/sec	-	-
		32	Ent Angular Vel.	rad/sec	-	-
		32	Ent Angular Vel.	rad/sec	-	-
96	Entity Markings	8	Character Set	-	0	Unused
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
32	Capabilities	32		-	0	No capabilities
nx128	Articulation Parameters	8	Param. Type Desig.	Not Applicable - F-18 WSSF generates no Articulation Parameters for this Exercise		
		8	Change			
		16	ID - attached to -			
		32	Parameter Type			
		64	Parameter Value			

Note: (1) LSB of 32-bit word is set to "1" to indicate use of absolute (UTC) time stamp. Value of the 2nd LSB of the 32-bit word is $3600/(2^{31} - 1)$ or 1.67e-6 sec.

Table C1-2. Target Entity State PDU

Field Size (Bits)	Category	No. Bits	Function	PDU Data Units	Enum	Enumeration Meaning
96	PDU Header	8	Protocol Version	-	4	DIS Ver 2.0.4
		8	Exercise ID	-	1	JADS LSP
		8	PDU Type	-	1	Entity State
		8	Protocol Family	-	1	Entity Info/Inter
		32	Time Stamp (1)	sec	-	
		16	Length	octects	144	PDU=144 octets
		16	Padding	dim	-	-
48	Entity ID	16	Site	-	3	WSIC
		16	Application	-	1	F-14 Simul
		16	Entity	-	1	Target
8	Force ID	8		-	2	Opposing
8	# Artic. Param	8		-	0	(none)
64	Entity Type	8	Entity Kind	-	1	Platform
		8	Domain	-	2	Air
		16	Country	-	225	United States
		8	Category	-	1	Ftr/Air Defense
		8	Subcategory	-	2	F-14 Tomcat
		8	Specific	-	0	(other)
		8	Extra	-	0	(other)
64	Alternative Entity Type	8	Entity Kind	-	1	Platform
		8	Domain	-	2	Air
		16	Country	-	225	United States
		8	Category	-	1	Ftr/Air Defense
		8	Subcategory	-	9	F-18 Hornet
		8	Specific	-	1	F/A-18
		8	Extra	-	0	(other)
96	Entity Linear Velocity	32	X	m/sec	-	-
		32	Y	m/sec	-	-
		32	Z	m/sec	-	-
192	Entity Location	64	X (WGS84 world coord)	meters	-	-
		64	Y (WGS84 world coord)	meters	-	-
		64	Z (WGS84 world coord)	meters	-	-
96	Entity Orientation	32	Psi (Euler angle)	rad	-	-
		32	Theta (Euler angle)	rad	-	-
		32	Phi (Euler angle)	rad	-	-
32	Entity Appear	32		-	0	No appearance

Table C1-2. Target Entity State PDU (Concluded)

Field Size (Bits)	Category	No. Bits	Function	PDU Data Units	Enum	Enumeration Meaning
320	Dead Reckoning Parameters	8	Dead Reck. Algor.	-	2	DRM(F,P,W)
		120	(Other - unused)	-	-	
		32	Ent Linear Accel - X	m/sec^2	-	-
		32	Ent Linear Accel - Y	m/sec^2	-	-
		32	Ent Linear Accel - Z	m/sec^2	-	-
		32	Ent Angular Vel.	rad/sec	-	-
		32	Ent Angular Vel.	rad/sec	-	-
		32	Ent Angular Vel.	rad/sec	-	-
96	Entity Markings	8	Character Set	-	0	Unused
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
32	Capabilities	32		-	0	No capabilities
nx128	Articulation Parameters	8	Param. Type Desig.	Not Applicable - F-14D WSIC generates no Articulation Parameters for this Exercise		
		8	Change			
		16	ID - attached to -			
		32	Parameter Type			
		64	Parameter Value			

Note: (1) LSB of 32-bit word is set to "1" to indicate use of absolute (UTC) time stamp. Value of the 2nd LSB of the 32-bit word is $3600/(2^{31} - 1)$ or 1.67e-6 sec.

Table C1-3. Missile Entity State PDU

Field Size (Bits)	Category	No. Bits	Function	PDU Data Units	Enum	Enumeration Meaning
96	PDU Header	8	Protocol Version	-	4	DIS Ver 2.0.4
		8	Exercise ID	-	1	JADS LSP
		8	PDU Type	-	1	Entity State
		8	Protocol Family	-	1	Entity Info/Inter
		32	Time Stamp (1)	sec	-	
		16	Length	octects	144	PDU=144 octets
		16	Padding	dim	-	-
48	Entity ID	16	Site	-	2	SIMBAY
		16	Application	-	1	AIM-9 Simul
		16	Entity	-	1	Missile
8	Force ID	8		-	1	Friendly
8	# Artic. Param	8		-	0	(none)
64	Entity Type	8	Entity Kind	-	2	Munition
		8	Domain	-	1	Anti-air
		16	Country	-	225	United States
		8	Category	-	1	Guided
		8	Subcategory	-	1	AIM-9 Sidewinder
		8	Specific	-	5	AIM-9R
		8	Extra	-	0	(other)
64	Alternative Entity Type	8	Entity Kind	-	1	Platform
		8	Domain	-	2	Air
		16	Country	-	225	United States
		8	Category	-	1	Ftr/Air Defense
		8	Subcategory	-	9	F-14 Tomcat
		8	Specific	-	0	(other)
		8	Extra	-	0	(other)
96	Entity Linear Velocity	32	X	m/sec	-	-
		32	Y	m/sec	-	-
		32	Z	m/sec	-	-
192	Entity Location	64	X (WGS84 world coord)	meters	-	-
		64	Y (WGS84 world coord)	meters	-	-
		64	Z (WGS84 world coord)	meters	-	-
96	Entity Orientation	32	Psi (Euler angle)	rad	-	-
		32	Theta (Euler angle)	rad	-	-
		32	Phi (Euler angle)	rad	-	-
32	Entity Appear	32		-	0	No appearance

Table C1-3. Missile Entity State PDU (Concluded)

Field Size (Bits)	Category	No. Bits	Function	PDU Data Units	Enum	Enumeration Meaning
320	Dead Reckoning Parameters	8	Dead Reck. Algor.	-	2	DRM(F,P,W)
		120	(Other - unused)	-	-	
		32	Ent Linear Accel - X	m/sec^2	-	-
		32	Ent Linear Accel - Y	m/sec^2	-	-
		32	Ent Linear Accel - Z	m/sec^2	-	-
		32	Ent Angular Vel.	rad/sec	-	-
		32	Ent Angular Vel.	rad/sec	-	-
		32	Ent Angular Vel.	rad/sec	-	-
96	Entity Markings	8	Character Set	-	0	Unused
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
		8		-	0	-
32	Capabilities	32		-	0	No capabilities
nx128	Articulation Parameters	8	Param. Type Desig.	Not Applicable - SIMLAB generates no Articulation Parameters for this Exercise		
		8	Change			
		16	ID - attached to -			
		32	Parameter Type			
		64	Parameter Value			

Note: (1) LSB of 32-bit word is set to "1" to indicate use of absolute (UTC) time stamp. Value of the 2nd LSB of the 32-bit word is $3600/(2^{31} - 1)$ or 1.67e-6 sec.

Table C1-4. Fire (Flare) PDU

Field Size (Bits)	Category	No. Bits	Function	PDU Data Units	Enum	Enumeration Meaning
96	PDU Header	8	Protocol Version	-	4	DIS Ver 2.0.4
		8	Exercise ID	-	1	JADS LSP
		8	PDU Type	-	2	Fire
		8	Protocol Family	-	2	Warfare
		32	Time Stamp (1)	sec	-	
		16	Length	octects	96	PDU=96 octets
		16	Padding	dim	-	-
48	Firing Entity ID	16	Site	-	3	WSIC
		16	Application	-	1	F-14 Simul
		16	Entity	-	1	Target
48	Target Entity ID	16	Site	-	2	SIMLAB
		16	Application	-	1	AIM-9 Simul
		16	Entity	-	1	Missile
48	Munition ID	16	Site	-	3	WSIC
		16	Application	-	1	F-14 Simul
		16	Entity	-	1	Flare
48	Event ID	16	Site	-	3	WSIC
		16	Application	-	1	F-14 Simul
		16	Entity	-	1	Flare Fire
32	Padding	32		dim	-	-
192	Location in World	64	X (WGS84 world coord)	meters	-	-
		64	Y (WGS84 world coord)	meters	-	-
		64	Z (WGS84 world coord)	meters	-	-

Table C1-4. Fire (Flare) PDU (Concluded)

Field Size (Bits)	Category		No. Bits	Function	PDU Data Units	Enum	Enumeration Meaning
128	Burst Descr	Mun Type	8	Entity Kind	-	2	Munition
			8	Domain	-	3	Anti-Guided Munition
			16	Country	-	225	United States
			8	Category	-	2	Ballistic
			8	Subcategory	-	0	(other)
			8	Specific	-	0	(other)
			8	Extra	-	0	(other)
			16	Warhead	-	3000	Illumination
			16	Fuze	-	2300	Timed, pyrotech
			16	Quantity	rounds	-	-
			16	Rate	rpm	-	-
96	Velocity		32	X (WGS84 world coord)	m/sec	-	-
			32	Y (WGS84 world coord)	m/sec	-	-
			32	Z (WGS84 world coord)	m/sec	-	-
32	Range		32		meters	-	-

Note: (1) LSB of 32-bit word is set to "1" to indicate use of absolute (UTC) time stamp. Value of the 2nd LSB of the 32-bit word is $3600/(2^{31} - 1)$ or 1.67e-6 sec.

Table C1-5. Fire (Missile) PDU

Field Size (Bits)	Category	No. Bits	Function	PDU Data		
				Units	Enum	Enumeration Meaning
96	PDU Header	8	Protocol Version	-	4	DIS Ver 2.0.4
		8	Exercise ID	-	1	JADS LSP
		8	PDU Type	-	2	Fire
		8	Protocol Family	-	2	Warfare
		32	Time Stamp (1)	sec	-	
		16	Length	octects	96	PDU=96 octets
		16	Padding	dim	-	-
48	Firing Entity ID	16	Site	-	1 (2)	WSSF
		16	Application	-	1	AIM-9 Simul
		16	Entity	-	2 (2)	Missile
48	Target Entity ID	16	Site	-	3	WSIC
		16	Application	-	1	F-14 Simul
		16	Entity	-	1	Target
48	Munition ID	16	Site	-	2	SIMLAB
		16	Application	-	1	AIM-9 Simul
		16	Entity	-	1	Missile
48	Event ID	16	Site	-	1 (2)	WSSF
		16	Application	-	1	AIM-9 Simul
		16	Entity	-	2 (2)	Missile Launch
32	Padding	32		dim	-	-
192	Location in World	64	X (WGS84 world coord)	meters	-	-
		64	Y (WGS84 world coord)	meters	-	-
		64	Z (WGS84 world coord)	meters	-	-

Table C1-5. Fire (Missile) PDU (Concluded)

Field Size (Bits)	Category		No. Bits	Function	PDU Data		
					Units	Enum	Enumeration Meaning
128	Burst Descr	Mun Type	8	Entity Kind	-	2	Munition
			8	Domain	-	1	Anti-Air
			16	Country	-	225	United States
			8	Category	-	1	Guided
			8	Subcategory	-	1	AIM-9 Sidewinder
			8	Specific	-	5	AIM-9R
			8	Extra	-	0	(other)
			16	Warhead	-	1000	High Explosive
			16	Fuze	-	3000	Proximity
			16	Quantity	rounds	-	-
			16	Rate	rpm	-	-
96	Velocity		32	X (WGS84 world coord)	m/sec	-	-
			32	Y (WGS84 world coord)	m/sec	-	-
			32	Z (WGS84 world coord)	m/sec	-	-
32	Range		32		meters	-	-

Notes: (1) LSB of 32-bit word is set to "1" to indicate use of absolute (UTC) time stamp. Value of the 2nd LSB of the 32-bit word is $3600/(2^{31} - 1)$ or 1.67e-6 sec.

(2) Although the WSSF initiates missile launch, the time of missle "fire", for data acquistion purposes shall be recorded at the time of actual missile separation. These data are generated by the SIMLAB vice the WSSF. However, in order to cause the data to appear as if the WSSF (Site =1) "launches" the missile (Site=2), the WSSF Site ID (1) is assigned to the SIMLAB for the Fire PDU. Likewise, the SIMLAB Site ID (2) is assigned to the "Entity" and the "Event" to encode an appearance that the WSSF "fired" the missile.

Table C1-6. Detonation PDU

Field Size (Bits)	Category	No. Bits	Function	PDU Data		
				Units	Enum	Enumeration Meaning
96	PDU Header	8	Protocol Version	-	4	DIS Ver 2.0.4
		8	Exercise ID	-	1	JADS LSP
		8	PDU Type	-	3	Detonation
		8	Protocol Family	-	2	Warfare
		32	Time Stamp (1)	sec	-	
		16	Length	octects	96	PDU=96 octets
		16	Padding	dim	-	-
48	Firing Entity ID	16	Site	-	2	SIMLAB
		16	Application	-	1	AIM-9 Simul
		16	Entity	-	1	Missile
48	Target Entity ID	16	Site	-	3	WSIC
		16	Application	-	1	F-14 Simul
		16	Entity	-	1	Target
48	Munition ID	16	Site	-	2	SIMLAB
		16	Application	-	1	AIM-9 Simul
		16	Entity	-	1	Missile
48	Event ID	16	Site	-	2	SIMLAB
		16	Application	-	1	AIM-9 Simul
		16	Entity	-	1	W/H Detonate
96	Velocity	32	X (WGS84 world coord)	m/sec	-	-
		32	Y (WGS84 world coord)	m/sec	-	-
		32	Z (WGS84 world coord)	m/sec	-	-
192	Location in World	64	X (WGS84 world coord)	meters	-	-
		64	Y (WGS84 world coord)	meters	-	-
		64	Z (WGS84 world coord)	meters	-	-

Table C1-6. Detonation PDU (Concluded)

Field Size (Bits)	Category		No. Bits	Function	PDU Data		
					Units	Enum	Enumeration Meaning
128	Burst Descr	Mun Type	8	Entity Kind	-	2	Munition
			8	Domain	-	1	Anti-Air
			16	Country	-	225	United States
			8	Category	-	1	Guided
			8	Subcategory	-	1	AIM-9 Sidewinder
			8	Specific	-	5	AIM-9R
			8	Extra	-	0	(other)
			16	Warhead	-	1000	High Explosive
			16	Fuze	-	3000	Proximity
			16	Quantity	rounds	-	1 round
			16	Rate	rpm	-	-
96	Location in Entity Coordinates		32	X (target coordinates)		-	-
			32	Y (target coordinates)		-	-
			32	Z (target coordinates)		-	-
8	Detonation Results		32			2	Entity Proximity Detonation
8	# Artic. Param		8			-	-
16	Padding		16			-	-
nx128	Articulation Parameters		8	Param Type Desig	Not Applicable - SIMLAB Missile/Warhead does not generate Articulation Parameters		
			8	Change			
			16	ID - attached to -			
			32	Parameter Type			
			64	Parameter Value			

Note: (1) LSB of 32-bit word is set to "1" to indicate use of absolute (UTC) time stamp. Value of the 2nd LSB of the 32-bit word is $3600/(2^{31} - 1)$ or 1.67e-6 sec.

APPENDIX D

INTERFACE CONTROL DOCUMENT

for the

SYSTEM INTEGRATION TEST

LINKED SIMULATORS PHASE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

D.1.0 SCOPE

D.1.1 IDENTIFICATION

The Joint Advanced Distributed Simulation (JADS) Program is chartered to investigate the utility of using Advanced Distributed Simulation (ADS) as a methodology for both developmental and operational test and evaluation, as well as identifying growth requirements needed to better meet the needs of the test and evaluation (T&E) community. JADS Joint Test and Evaluation (JT&E) is the implementation of this investigation.

As currently approved, JADS JT&E includes two tests: (1) A System Integration Test (SIT) and (2) an End-to-End (ETE) test. The SIT examines the use of ADS technology to support air-to-air missile testing. The ETE examines the use of ADS technology to support C4I system testing. The SIT is implemented in two phases: (1) A Live Fly Phase and (2) a Linked Simulators Phase (LSP).

This is the Interface Control Document (ICD) for the LSP of the JADS JT&E program. The LSP includes three test missions: (1) A Verification and Validation (V&V) Mission (Mission #1), (2) a Parametric Mission (Mission #2), and (3) a Data Latency Mission (Mission #3).

D.1.2 SYSTEM OVERVIEW

The LSP test configuration, shown in Figure D-1, is comprised of the F/A-18 Weapon System Support Facility (WSSF) and the AIM-9 hardware-in-the-loop Simulation Laboratory (SIMLAB) both located at Naval Air Warfare Center (NAWCWPNS), China Lake, CA; the F-14D Weapons System Integration Center (WSIC) and the Battle Management Interoperability Center (BMIC) both located at NAWCWPNS, Point Mugu, CA; and the JADS Test Control and Analysis Center (TCAC) located at Kirtland AFB, NM. These facilities are networked via a subset of the NAWCWPNS Real-Time Network (NRNet) as shown in Figure D-2 and Tables D-1 and C-2. All closed-loop simulation data flow between these facilities is via standard Distributed Interactive Simulation (DIS) Protocol Data Units (PDUs), Version 2.0.4, transmitted over this network. The network terminates in a Network Interface Unit (NIU) at each facility. The NIU interfaces with a Simulation Interface Unit (SIU) which, in turn interfaces with the high-fidelity simulation applications running autonomously at each facility as shown in Figure D-3. The aggregate NIU/SIU hardware/software systems at each facility implement all required communications functions defined by the OSI 7-Layer Reference Model. In addition to the DIS network, a MIL-STD-1553 Networking System (MNS-1) link, which is part of the NRNet, also connects the WSSF with the SIMLAB for the singular purpose of transmitting prelaunch missile preparation information from the WSSF to the SIMLAB. The facilities are also linked by STU-III voice communications.

The detailed network hardware diagram for the LSP is given in Annex 2.

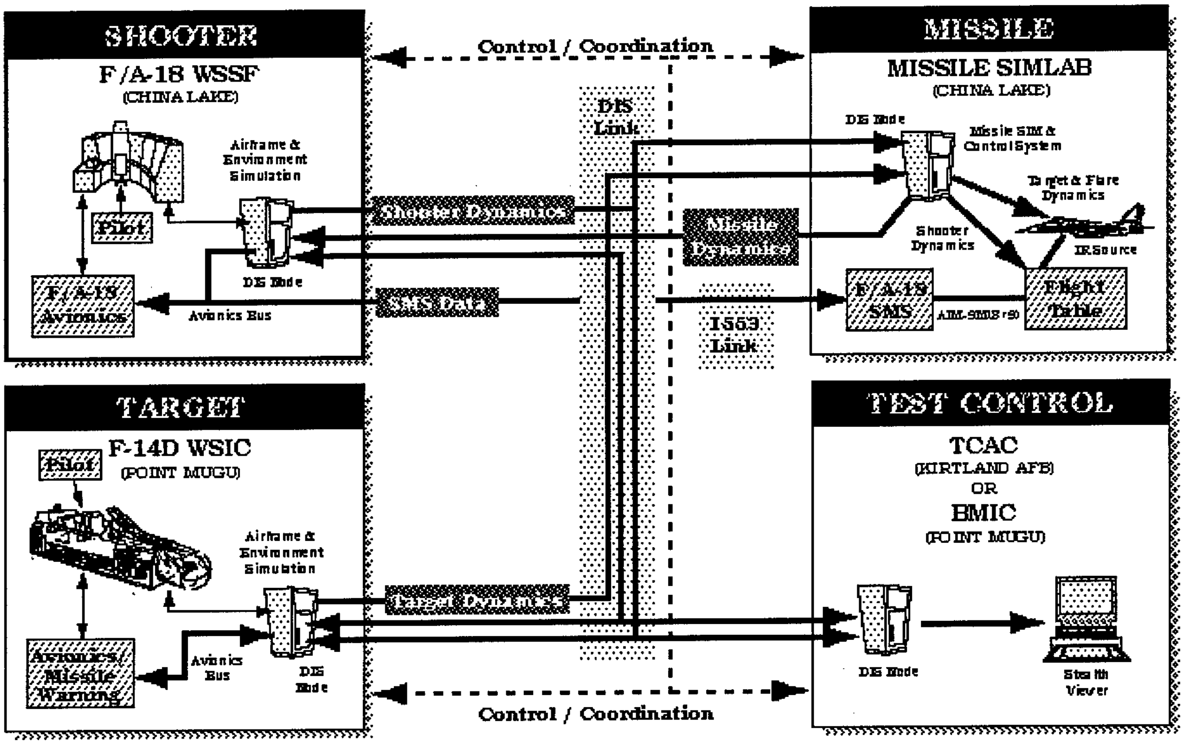


Figure D-1. JADS LSP Configuration

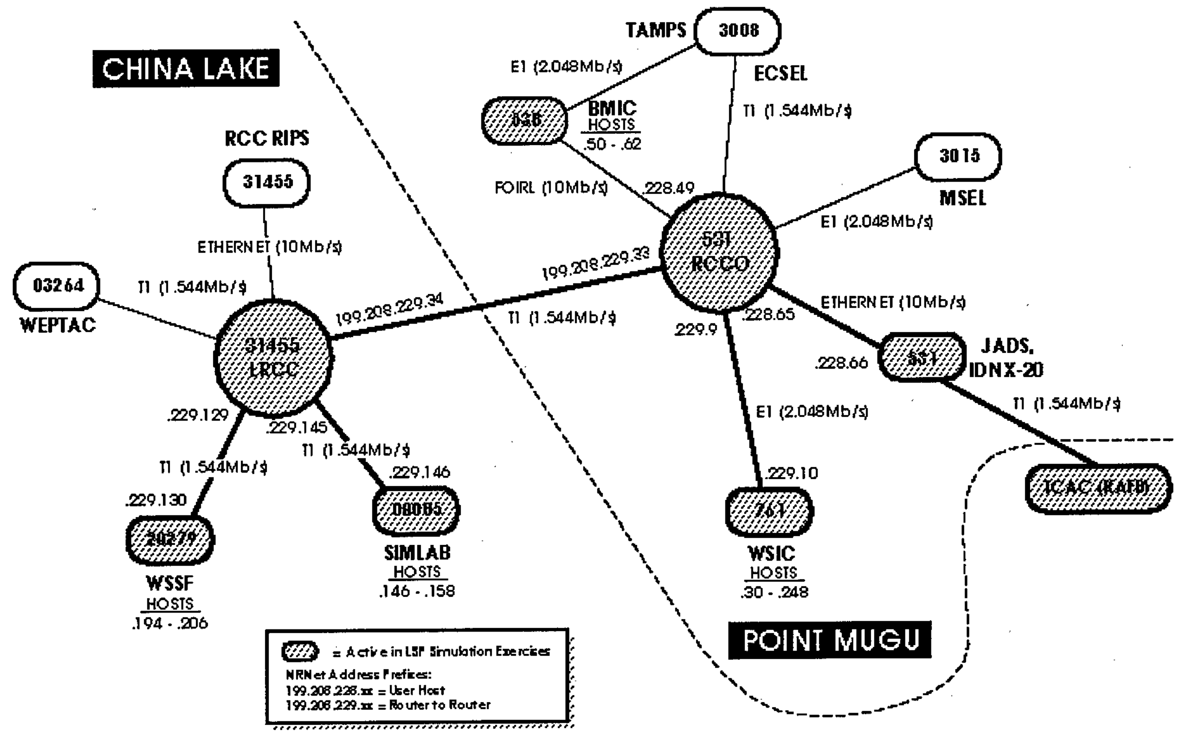


Figure D-2. NRNet Block Diagram

Table D-1. NRNet IP Address List

Site	IP Address	Equipment	Peripheral Device	Host IP Address Host/Host Brdcst	POC	Telephone No.
Point Mugu, Bldg. 531, RCCO						
	199.208.229.9	NRNet CN Router	S21-WSIC, Cisco Router		Brian Krinsley	(805) 989-9007
	199.208.229.33	NRNet CN Router	S24-LRCC, LN Router		Bernie Orleit	(805) 939-6980
	199.208.228.49	NRNet CN Router	E41-BMIC, Ethernet Bridge		Randal Taylor	(805) 989-9221
	199.208.228.65	NRNet CN Router	E42-JADS, IDNX-20		Maj. Steve Sturgeon	(505) 846-0528
Point Mugu, Bldg. 761, WSIC						
	199.208.229.10	NRNet Cisco Router	Serial 0-PM, CN Router		Brian Krinsley	(805) 989-9007
	192.68.204.249	NRNet Cisco Router	Ethernet 0-WSIC	.30 - .248 .255	Brian Krinsley	(805) 989-9007
Point Mugu, Bldg. 53, BMIC						
	199.208.228.50 - .62	Ethernet Bridge	Ethernet Port 1	.50 - .62 .63	Randal Taylor	(805) 989-9221
Point Mugu, Bldg. 531, JADS (KAFB)						
	199.208.228.66	IDNX-20 Router	Ethernet 0	.65 - .78 .79	Maj. Steve Sturgeon	(505) 846-0528
China Lake, Bldg. 31445, LRCC						
	199.208.229.34	NRNet LN Router	S21-PM, CN Router		Joel Bossoletti	(805) 989-0902
	199.208.229.129	NRNet LN Router	S22-WSSF, LN Router		Marc Williams	(619) 939-5127
	199.208.229.145	NRNet LN Router	S24, SIMLAB, Cisco Router		Ed Slack	(619) 927-1457
China Lake, Bldg. 20279, WSSF						
	199.208.229.130	NRNet LN Router	S21-LRCC, LN Router		Marc Williams	(619) 939-5127
	199.208.228.193	NRNet LN Router	E31-WSSF, HP 735	.194 - .206 .207	Marc Williams	(619) 939-5127
China Lake, Bldg. 00005, SIMLAB						
	199.208.229.146	NRNet Cisco Router	Serial 0-LRCC, LN Router		Bernie Orleit	(619) 939-6980
	199.208.228.145	NRNet Cisco Router	Ethernet 0	.146 - .158 .159	Ed Slack	(619) 927-1457

Table D-2. LSP Router Hardware and Software

Location	Laboratory	Router Hardware	Router Software	Remarks
Point Mugu	RCCO (Bldg. 531)	Bay Networks (Wellfleet) CN Router	Version 7.80, Fix 7	
	WISC	Cisco 2501	Version 10.2 (13)	
	RCCO (Bldg. 531)	IDNX-20	TBD	JADS KAFB WAN Interface
China Lake	LRCC (Bldg. 31455)	Bay Networks (Wellfleet) LN Router	Version 5.77	
	WSSF	Cisco 2501	Version 10.3 (12)	
	SIMLAB	Cisco 2501	Version 10.3 (7)	

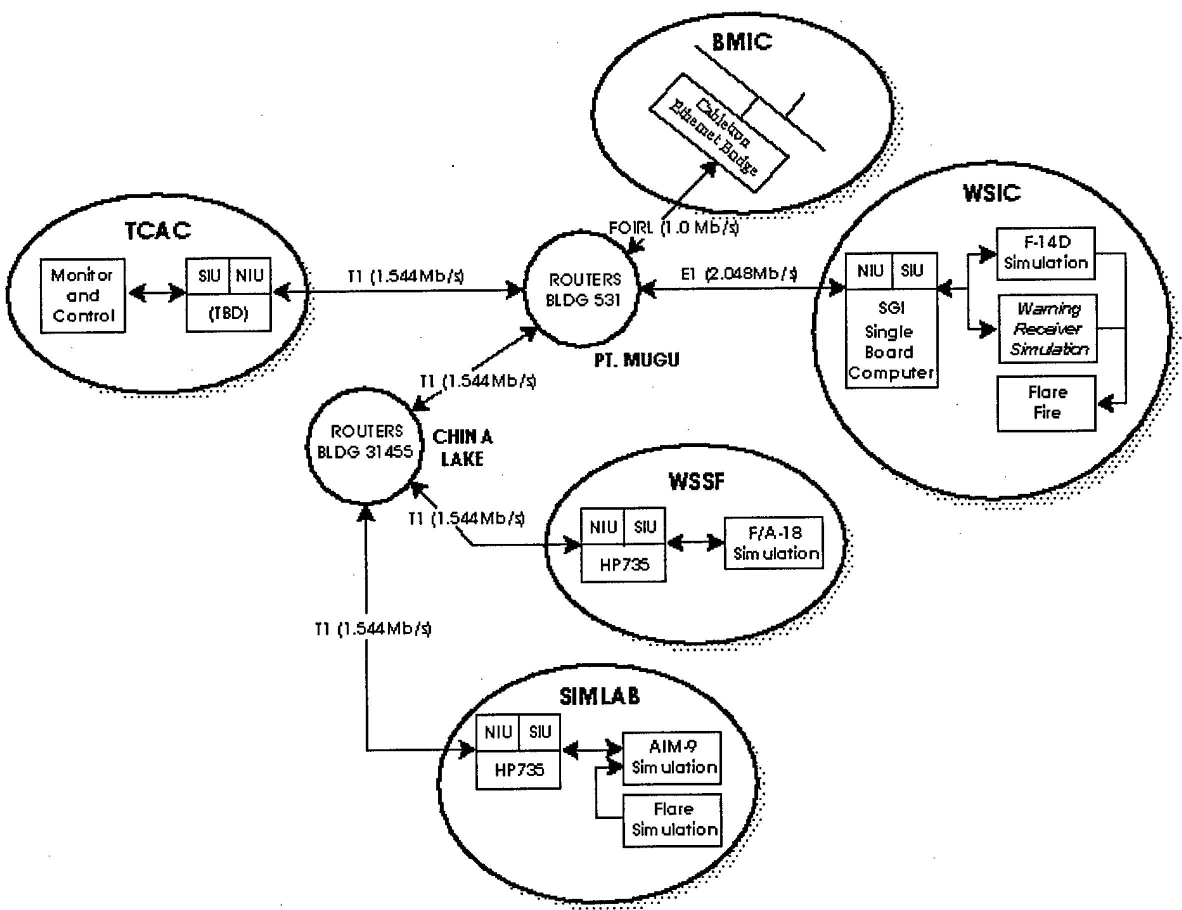


Figure D-3. Network Configuration for LSP Simulation Exercises

D.1.3 DOCUMENT OVERVIEW

This ICD applies only to the LSP of the JADS JT&E and describes only those interface requirements on the "network side" of the data entry/exit point of the NIU (or equivalent) located at each facility site. Any interface requirements of the NIU and/or SIU are beyond the scope of this document. Additionally, this ICD does not address the interface requirements related to any simulation exercise beyond those described in the Test Activity Plan for the JADS LSP.

Standard DIS terminology, as defined in the Standard for Distributed Interactive Simulation - Application Protocols, Version 2.0 Fourth Draft, is used throughout this document to describe elements, processes, functions, etc.

D.2.0 APPLICABLE DOCUMENTS

D.2.1 GOVERNMENT DOCUMENTS

None

D.2.2 NON- GOVERNMENT DOCUMENTS

The following documents to the issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and contents of this specification, the contents of this specification shall be considered a superseding requirement.

Standard for Distributed Interactive Simulation -- Application Protocols Version 2.0 Fourth Draft, Institute for Simulation and Training, University of Central Florida, 4February 1994

This document is available from:

Institute for Simulation and Training
3280 Progress Drive
Orlando, FL 32862

IEEE 754-1985- IEEE Standard for Binary Floating Point Arithmetic, IEEE Product #SH10116

This document is available from:

IEEE Inc.
445 Hoes Lane
P.O. Box 1331
Piscataway, N.J. 08855-1331
Telephone: 1-800-678-IEEE

ISO 7498- Information Processing Systems - Open Systems Interconnection - Basic Reference Model

This document is available from:

American National Standards Institute (ANSI)
Sales Department
11 West 42nd Street
New York, NY 10036
Telephone: 212-642-4900

IST-CR--95-14 Enumeration and Bit-encoded Values for use with IEEE 1278.1-1995, Standard for Distributed Interactive Simulation Protocols

This document is available from:

University of Central Florida
Center for Continuing Education
Orlando, FL 32816-0177
Telephone: 407-249-6100

Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal Agencies.

D.3.0 INTERFACE SPECIFICATION

D.3.1 INTERFACE DIAGRAMS

Figure D-4 illustrates the functional data flow between each of the simulation entities. In all cases but one, data is transmitted via standardized DIS PDUs (Version 2.0.4). The one exception is prelaunch missile preparation initial conditions data that are generated in the WSSF and transmitted to the missile in the SIMLAB via an MNS-1 real-time network using TCP/IP protocol over Ethernet. Detailed contents and formats of each PDU are found in Appendix C. Content and format of the MNS-1 interface is found in Annex 1 to this appendix.

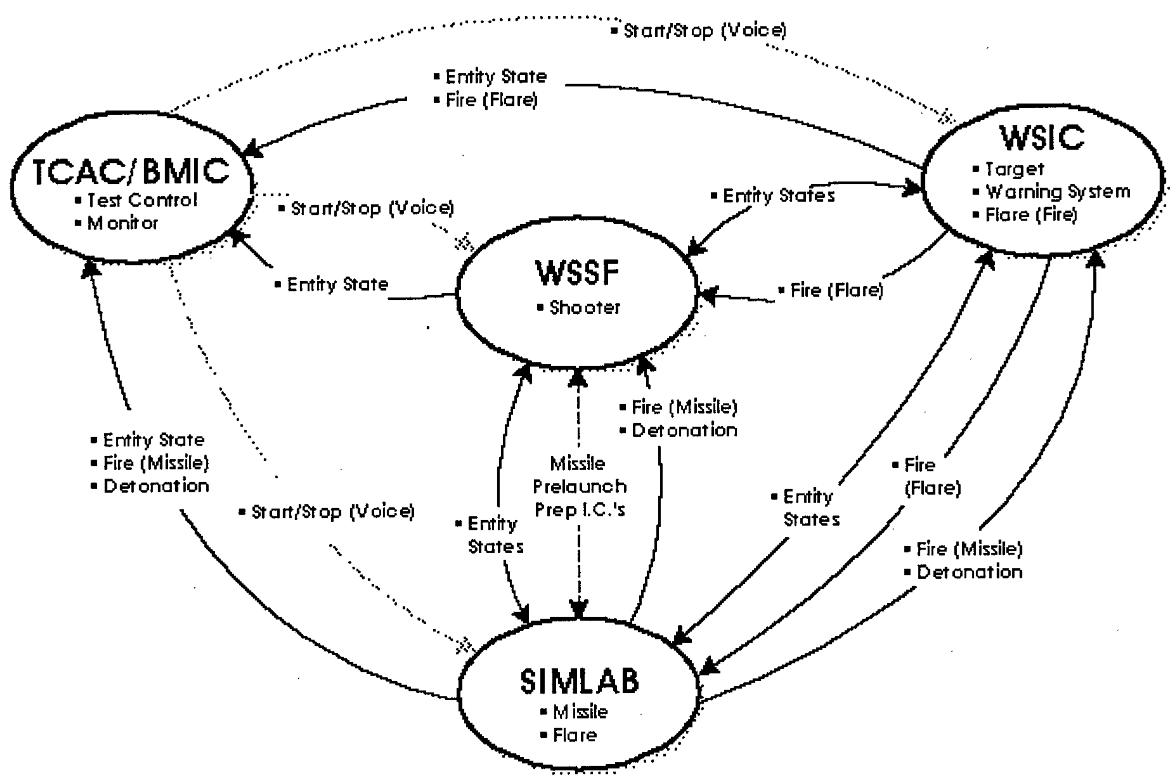
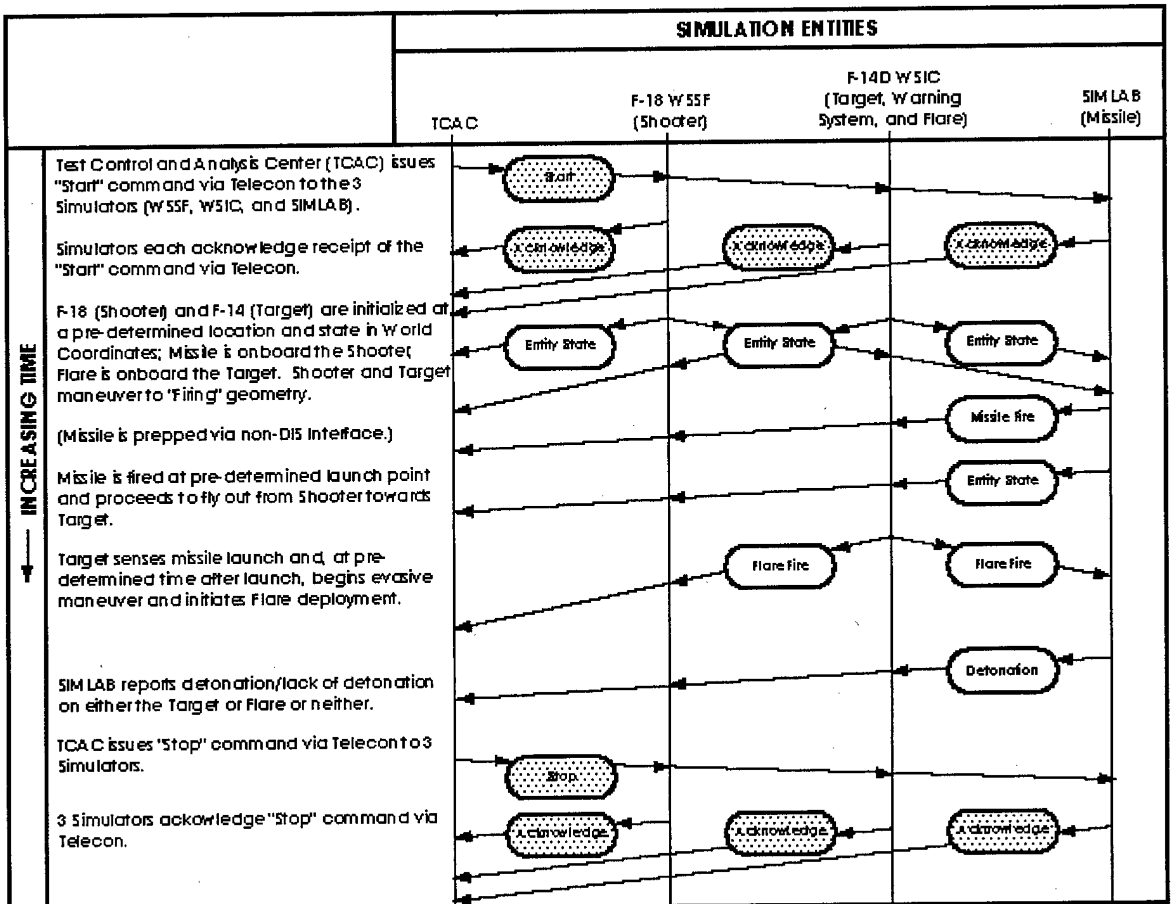


Figure D-4. Functional Data Flow Diagram for LSP Simulation Exercise

Origin, sequence, and utilization of PDUs are shown in FigureD-5.



NOTES: Nomenclature within ⬭ denotes type of PDU; "Tail" of arrow the origin of the PDU, and "Head" of arrow "Users" of the PDU.
⬭ Functions of Start/Stop/Acknowledge implemented via Telecon vice PDU's.

Figure D-5. Origin, Sequence, and Utilization of Protocol Data Units (PDUs) for LSP Tests

Each facility site ("simulator") generates one or more "Simulation Entities", as defined in DIS Standard Version 2.0.4, and are described as follows:

<u>F-14D Weapons System Integration Center (WSIC)</u>

The F-14D WSIC is a full, 6-degree-of-freedom, real-time, closed-loop, hardware-in-the-loop simulation laboratory that incorporates actual F-14D avionics, controls and displays, and tactical software in a 1:1 mockup of the forward module of the F-14D. The WSIC generates two simulation entities for the LSP application exercise: (1) the "target" against which the missile is fired and (2) a "warning receiver" that detects that the target has been fired upon and cues the expenditure of countermeasures (a "flare").

AIM-9 Simulation Laboratory (SIMLAB)

The SIMLAB is a 6-degree-of-freedom, real-time, closed-loop, hardware-in-the-loop simulation laboratory that incorporates actual missile guidance and control hardware and software. The SIMLAB is capable of incorporating various missile systems, but for the LSP exercises will incorporate an AIM-9 Sidewinder missile. The SIMLAB is also capable of generating computer-controlled target, clutter, and counter-measures signatures. For the LSP the SIMLAB generates two simulation entities: (1) the missile that is fired against the "target" (WSIC) by the F/A-18 "shooter" (WSSF) and (2) the characteristics of the "flare" deployed by the "target" against the missile.

F/A-18 Weapon System Support Facility (WSSF)

The WSSF is similar to the WSIC in both function and capabilities. The primary difference is the WSSF avionics and controls and displays are not mounted in an aircraft mockup, but they are mounted in conventional laboratory equipment bays and/or workstations. The WSSF generates one simulation entity: the F/A-18 "shooter."

Test Control and Analysis Center (TCAC)

The TCAC, or the BMIC, provides overall simulation exercise control and monitoring and does not generate any "simulation entity" in terms of an active player in the simulated scenario. Test control and monitoring of LSP Mission #1 will be exercised from the BMIC. Test control and monitoring of LSP Missions #2 and #3 will be exercised from the TCAC. References in this document to the TCAC also apply to the BMIC when the BMIC is used for test control.

DIS Protocol

DIS Version 2.0.4 defines 27 PDU types organized into 6 protocol families. In general, a PDU is:

(a) a packet of application data containing (1) identification of information exchanged, (2) structured format of the information, (3) circumstances under which the information is transmitted, (4) action required upon receipt (if any), (5) state variable updates, and (6) constraints governing the exchange of information.

(b) a pointer to databases contained in each simulation application.

(c) required for interoperability.

The LSP simulation exercises require utilization of only 3 of the 27 PDUs from 2 of the 6 families. They are:

Entity Information/Interaction (family)

Entity State PDU

Warfare (family)

Fire PDU
Detonation PDU

D.3.2 F-14 WSIC INTERFACE SPECIFICATIONS

The F-14 WSIC shall generate the target and warning system simulation entities.

D.3.2.1 F-14 WSIC INTERFACE REQUIREMENTS

All F-14D WSIC software elements run autonomously and concurrent with the software elements of the TCAC, WSSF, and SIMLAB. Synchronization protocol for supporting concurrent operation is embedded in the NIU software at the WSIC and is beyond the scope of this document.

DIS PDUs will be used to interface the F-14D WSIC with the network. Specifically, Entity State (target) and Fire (flare) PDUs will be generated by the WSIC. Fire (missile), Detonation, and Entity State (missile and shooter) PDUs will be received by the WSIC.

D.3.2.2 F-14 WSIC DATA REQUIREMENTS

Appendix C, Annex 1 lists the details of the PDU's output from the F-14D WSIC to the network. They are:

Table C1-2 F-14D WSIC Entity State (Target) PDU
Table C1-4 F-14D WSIC Fire (Flare) PDU

Table D-3 lists the PDU inputs required by the F-14D WSIC from the network.

Table D-3. PDU Inputs to F-14D WSIC

PDU Input to F-14D	From	Reference
Entity State (shooter)	F/A-18 WSSF	Table C1-1
Fire (missile)	SIMLAB	Table C1-5
Detonation	SIMLAB	Table C1-6
Entity State (missile)	SIMLAB	Table C1-3

D.3.2.2.3 Data Encryption

All PDU data from the WSIC NIU to the network shall be encrypted before being transmitted to the network. All PDU data received from the network shall be decrypted before being transmitted to the NIU.

UTC time in IRIG-B format will be used to time stamp all data recorded at the WSIC.

D.3.3 SIMLAB INTERFACE SPECIFICATIONS

The SIMLAB shall generate the missile simulation entity and flare characteristics.

D.3.3.1 SIMLAB INTERFACE REQUIREMENTS

All SIMLAB software elements run autonomously and concurrent with the software elements of the TCAC, WSSF, and WSIC. Synchronization protocol for supporting concurrent operation is embedded in the NIU software at the SIMLAB which is beyond the scope of this document.

DIS PDUs will be used to interface the SIMLAB with the network. Specifically, Entity State (missile), Fire (missile) and Detonation PDUs will be generated by the SIMLAB. Fire (flare), and Entity State (shooter and target) PDUs will be received by the SIMLAB.

MIL-STD-1553 message traffic supported by TCP/IP protocol will be received by the SIMLAB from the F/A-18 WSSF via the MNS-1 real-time network. This message traffic is used exclusively for sending missile prelaunch preparation information from the shooter to the missile and receiving the missile response during the missile launch-to-eject (LTE) cycle. Detailed specifications for this message traffic are contained in Annex 1 to this appendix.

D.3.3.2 SIMLAB DATA REQUIREMENTS

D.3.3.2.1 Data Recording Requirements

Appendix C, Table C-4 lists the SIMLAB data recording requirements. These data are recorded locally at the SIMLAB facility.

D.3.3.2.2 SIMLAB PDU Descriptions

Appendix C, Annex 1 lists the details of the PDU's output from the SIMLAB to the network. They are:

Table C1-5 SIMLAB Fire (missile) PDU
Table C1-3 SIMLAB Entity State (missile) PDU
Table C1-6 SIMLAB Detonation (missile) PDU

Table D-4 lists the PDU inputs required by the SIMLAB from the network.

Table D-4. PDU Inputs to SIMLAB

PDU Input to SIMLAB	From	Reference
Entity State (shooter)	F/A-18 WSSF	Table C1-1
Fire (flare)	F-14D WSIC	Table C1-4
Entity State (target)	F-14D WSIC	Table C1-2

D.3.3.2.3 Data Encryption

All PDU data from the SIMLAB NIU to the network shall be encrypted before being transmitted to the network. All PDU data received from the network shall be decrypted before being transmitted to the NIU.

UTC time in IRIG-B format will be used to time stamp all data recorded at the SIMLAB.

D.3.4 F/A-18 WSSF INTERFACE SPECIFICATIONS

The F/A-18 WSSF shall generate the shooter entity.

D.3.4.1 F/A-18 WSSF INTERFACE REQUIREMENTS

All F/A-18 WSSF software elements run autonomously and concurrent with the software elements of the TCAC, WSIC, and SIMLAB. Synchronization protocol for supporting concurrent operation is embedded in the NIU software at the WSSF which is beyond the scope of this document.

DIS PDUs will be used to interface the F/A-18 WSSF with the network. Specifically, Entity State (shooter) PDUs will be generated by the WSSF and Fire (missile and countermeasures), Entity States (missile and target), and Detonation PDUs will be received by the WSSF.

MIL-STD-1553 message traffic supported by TCP/IP protocol will be transmitted via the MNS-1 real-time network from the F/A-18 WSSF to the SIMLAB. This message traffic is used exclusively for sending missile prelaunch preparation information from the shooter to the missile and receiving the missile response during the missile LTE cycle. Detailed specifications for this message traffic is contained in Annex 1 to this appendix.

D.3.4.2 F/A-18 WSSF DATA REQUIREMENTS

D.3.4.2.1 Data Recording Requirements

Appendix B, Table B-2 lists the F/A-18 WSSF data recording requirements. These data are recorded locally at the WSSF facility.

D.3.4.2.2 F/A-18 WSSF PDU Descriptions

Appendix C, Annex 1, Table C1-1 lists the detailed PDU output from the F/A-18 WSSF to the network.

Table D-5 lists the PDU inputs required by the F/A-18 WSSF from the network.

Table D-5. PDU Inputs to F/A-18 WSSF

PDU Input to F/A-18 WSSF	From	Reference
Entity State (target)	F-14D WSIC	Table C1-2
Fire (flare)	F-14D WSIC	Table C1-4
Entity State (missile)	SIMLAB	Table C1-3
Fire (missile)	SIMLAB	Table C1-5
Detonation	SIMLAB	Table C1-6

D.3.4.2.3 Data Encryption

All PDU data from the WSSF NIU to the network shall be encrypted before being transmitted to the network. All PDU data received from the network shall be decrypted before being transmitted to the NIU.

UTC time in IRIG-B format will be used to time stamp all data recorded at the WSSF.

D.3.5 TCAC INTERFACE SPECIFICATIONS

D.3.5.1 TCAC INTERFACE REQUIREMENTS

The TCAC shall provide overall test coordination, control and monitoring.

All TCAC software applications run autonomously and concurrent with the software applications of the WSSF, WSIC, and SIMLAB. Synchronization protocol for supporting concurrent operation is embedded in the NIU software at TCAC. This protocol is not within the scope of this document.

DIS PDUs will be used to interface the TCAC with the network. Specifically, Entity State, Fire and Detonation PDUs will be received by the TCAC from the network.

D.3.5.2 TCAC DATA REQUIREMENTS

D.3.5.2.1 Data Recording Requirements

Appendix C, Table C-5 lists the TCAC data recording requirements. These data are recorded locally at the TCAC facility.

D.3.5.2.2 TCAC PDU Descriptions

TCAC does not generate PDU outputs for the LSP missions.

Table D-6 lists the PDU inputs required by the TCAC from the network.

Table D-6. PDU Inputs to TCAC

PDU Input to TCAC	From	Reference
Entity State (shooter)	F/A-18 WSSF	Table C1-1
Entity State (target)	F-14D WSIC	Table C1-2
Entity State (missile)	SIMLAB	Table C1-3
Fire (flare)	F-14D WSIC	Table C1-4
Fire (missile)	SIMLAB	Table C1-5
Detonation	SIMLAB	Table C1-6

D.3.5.2.3 Data Encryption

PDU data transmitted from the TCAC shall be encrypted to facilitate data processing consistency of all received PDU traffic at other facility sites on the network. All PDU data received at the TCAC from the network shall be decrypted before being transmitted to the TCAC NIU.

D.3.5.2.4 UTC time in IRIG-B format will be used to time stamp all data recorded at the TCAC.

ANNEX 1

MNS-1 INTERFACE DESCRIPTION

F/A-18 WSSF MIL-STD-1553 NETWORKING SYSTEM (MNS-1)

This appendix defines the message traffic used to communicate between two or more MNS-1 real-time network interfaces. The MNS-1s are used by the F/A-18 Weapon System Support Facility (WSSF) to virtually extend the F/A-18 MIL-STD-1553 Avionics Bus over long distances allowing avionics subsystems to be remotely located. The MNS-1 located in the F/A-18 WSSF is identified as the Local node, while one or more MNS-1s located at other sites are identified as Remote nodes. Data is transferred between the Local and Remote MNS-1 systems using TCP/IP protocol over Ethernet. All data words contain 16-bits. Each MNS-1 message is preceded with a two-word header which contains a -1 followed by a 1, and a two-word trailer which contains a -1 followed by a 2. The following describe all the messages used to connect, initialize, coordinate, and pass data between sites.

D1.1.0 LOCAL-TO-REMOTE MESSAGES

D1.1.1 Command Built-In Test (BIT) Message

Word 1 - Message ID = 3

D1.1.2 Status Request Message

Word 1 - Message ID = 4

D1.1.3 Initialize/Setup Message

Word 1 - Message ID = 6
Word 2 - Number of 1553 Message Groups (RT/SAs) to follow

Word 3 - Remote MNS-1 Node Number
Word 4 - 1553 Remote Terminal (RT) Number
Word 5 - 1553 Subaddress (SA) Number
Word 6 - 1553 RT/SA Word Count
Word 7 - 1553 RT/SA Communication Rate
Word 8 - 1553 RT Device Type (Mil-Std-1553A or B)

Repeat 3-8 for each 1553 Message Group identified in Word 2

D1.1.4 Real-Time Data Message

Word 1 - Message ID = 7
Word 2 - Local Message Count
Word 3 - Remote Message Count Echo
Word 4 - Discrete Signals 1-16
Word 5 - Discrete Signals 17-32
Word 6 - Discrete Signals 33-48
Word 7 - Discrete Signals 49-64
Word 8 - Number of 1553 Message Groups (RT/SAs) to Follow

Word 9 - RT/SA Message Type (bcrt, type of mode code)
Word 10 - RT Number
Word 11 - SA Number
Word 12 - Word Count
Word 13+ - Data Words for this RT/SA Message

Repeat 9-13+ for each 1553 Message Group identified in Word 8

D1.1.5 Start Real-Time Message

Word 1 - Message ID = 9

D1.1.6 Halt Real-Time Message

Word 1 - Message ID = 10

D1.1.7 End Program Message

Word 1 - Message ID = 11

D1.2.0 REMOTE-TO-LOCAL MESSAGES

D1.2.1 Status Response Message

Word 1 - Message ID = 4
Word 2 - Remote Node Number
Word 3 - 1553 ABI BIT Results (pass/fail/untested)
Word 4 - Clock Timer BIT Results (pass/fail/untested)
Word 5 - Remote Echo Word
Word 6 - Initialized (true/false)
Word 7 - Current State (real-time/not real-time)

D1.2.2 Real-Time Data Message

Word 1 - Message ID = 8
Word 2 - Remote Message Count
Word 3 - Local Message Count Echo
Word 4 - Discrete Signals 1-16
Word 5 - Discrete Signals 17-32
Word 6 - Discrete Signals 33-48
Word 7 - Discrete Signals 49-64
Word 8 - Number of 1553 Message Groups (RT/SAs) to follow

Word 9 - RT Number
Word 10 - SA Number
Word 11 - RT/SA Status (rtbc on/off, bcrt response/no response)
Word 12 - Word Count
Word 13+ - Data Words for this RT/SA Message

Repeat 9-13+ for each 1553 Message Group identified in Word 8

ANNEX 2

LSP NETWORK HARDWARE DIAGRAM

APPENDIX E

INTEGRATED TEST PROCEDURES

for the

SYSTEM INTEGRATION TEST

LINKED SIMULATORS PHASE

TABLE OF CONTENTS

LINKED SIMULATORS PHASE

MASTER TEST CONTROL CHECKLIST

DAY BEFORE TEST

Test Controller: ______________________

Date: ______________ Lab Time: ________ to _________

In the spaces provided, record the time each action is completed.

1. _________ Ensure enough supplies for the entire test period are on hand (checklist, test cards, blank test controller log sheets, pens or pencils, scratch paper).

2. _________ Join the command voice conference net by dialing (619) 939-0010 (SIMLAB Site Supervisor will make the first call).

3. _________ Conduct communication checks with each Site Supervisor, Laboratory Supervisor and pilot.

4. _________ Confirm with the Network Coordinator that the support voice conference network is operating and all participants have checked in.

5. _________ Boot all equipment.

6. _________ Verify test control display clock is synchronized to the GPS clock.

7. _________ Confirm operational readiness of 2-D viewer and test control display.

8. _________ Verify with Site Supervisors and Network Coordinator that all equipment at each site is fully functional.

9. _________ Leave voice conference net.

10. _________ Ensure Legacy Supervisor has all still camera, video and communications equipment ready for setup.

11. _________ Brief mission.
    - A. ________ Discuss equipment readiness and any repairs necessary.
    - B. ________ Establish arrival times formission personnel.
    - C. ________ Review mission procedures and test cards.

12. _________ Coordinate repairs as necessary to prepare equipment for the next day (T-23hrs. to T-60 min.).

LINKED SIMULATORS PHASE

MASTER TEST CONTROL CHECKLIST

DAY OF TEST BEFORE TEST RUNS

Test Controller: ______________________

Date: ______________ Lab Time: ________ to _________

T-60 min.

1. Arrive on station and open written logs.
2. Test Controller ensure enough supplies for the entire test period are on hand (test cards, checklist, blank test execution log sheets, pen or pencil, scratch paper).
3. SIMLAB Site Supervisor initiate command voice communication network by calling the audio conference bridge # (619) 939-0010.
4. SIMLAB DIS logger operator initiate support voice communication network by calling the audio conference bridge # (619) 939-6338.
5. Ensure all system clocks are set to GMT (UTC).

T-60 to T-45 min.

6. Test Controller, Site Supervisors, Laboratory Supervisors and pilots join the command voice communication network by calling the audio conference bridge # (619) 939-0010.
7. Network Coordinator, SNAP operators and DIS logger operators join the support voice communication network by calling the audio conference bridge # (619) 939-6338.
8. Test Controller confirm operational readiness of 2-D viewer and test control display.
9. Network Coordinator initialize all files and ping each system.
10. Legacy Supervisor ensure all video equipment is in place and operational.

T-45 min.

11. Test Controller and Network Coordinator conduct communications checks on their voice conference net.
12. Logger operators report equipment status to the Network Coordinator.

T-15 min.

13. Site Supervisors and Network Coordinator report to the Test Controller readiness of sites and network for test.
14. Test Controller makes go/no go decision.

LINKED SIMULATORS PHASE

MASTER TEST CONTROL CHECKLIST

FOR EACH TEST RUN

Test Controller: ______________________

Date: ______________ Lab Time: ________ to _________

1. Execute test cards.
2. After each run determine whether to repeat the run or proceed to the next test point.
3. Instruct sites to archive data and the number of next run.
4. Terminate test.

LINKED SIMULATORS PHASE

MASTER TEST CONTROL CHECKLIST

END OF DAY

Test Controller: ____________________

Date: ______________ Lab Time: ________ to _________

1. _________ Direct Network Controller to start file transfers.
2. _________ Gather test execution logs and other notes.
3. _________ Leave voice conference net.
4. _________ Network Coordinator creates master data tape.
5. _________ Turn off all equipment.
6. _________ Conduct mission debrief.
   A. Problems encountered.
   B. Specific comments on individual runs.
   C. Equipment status.

LINKED SIMULATORS PHASE

NETWORK COORDINATOR CHECKLIST

DAY BEFORE TEST

Network Coordinator: ______________________

Date: ______________ Lab Time: ________ to _________

In the spaces provided, record the time each action is completed.

1. _________ Ensure enough supplies for the entire test period are on hand (checklist, blank hardware/software discrepancy and network coordinator log sheets, file name lists, pens or pencils, scratch paper, 4mm tape cartridges).

2. _________ Join the support voice conference net by dialing (619) 939-6338 (SIMLAB operator will make the first call).

3. _________ Conduct communication check with each SNAP and DIS logger operator.

4. _________ Boot all equipment.

5. _________ Verify with NETSNOOP that each logger is connected to the network.

6. _________ Verify that NTP is running.

7. _________ Synchronize the display clock to the NTP derived clock.

8. _________ Start NETLOOK and verify operation.

9. _________ Verify that all machines at the test control site are up.

10. _________ Verify that the DIS logger at each site is up and ready to receive PDUs.

11. _________ Verify that the DIS logger at each site is set to port 6996 and the exercise ID is 0.

12. _________ Direct the SIMLAB to replay a log file for remote machines to use for system checks. (May not be received by the WSSF)

13. _________ Verify that each site is receiving the log file.

14. _________ Using NETSNOOP verify that the appropriate network traffic is present on each network segment.

15. _________ Direct SIMLAB to stop playback.

LINKED SIMULATORS PHASE

NETWORK COORDINATOR CHECKLIST

16.________ Verify with the DIS logger operators at each site that all log files have been created and are empty. The format is: `mmddyy_test#_lab.lgr` (`ls -al /disk2/stricom/log/`)

17.________ Report the results of the system checks to the Test Controller.

18.________ Leave the voice conference net.

19.________ Attend mission brief.

20.________ Supervise repairs as necessary to prepare equipment for the next day (T-3 hrs. to T-60 min.).

LINKED SIMULATORS PHASE

NETWORK COORDINATOR CHECKLIST

DAY OF TEST BEFORE TEST RUNS

Network Coordinator: ______________________

Date: ______________ Lab Time: ________ to _________

In the spaces provided, record the time each action is completed.

1. _________ Arrive on site.
2. _________ Open written logs.
3. _________ Check supplies (clipboards, checklists, forms, file name lists, pens & pencils, scratch paper, backup media).
4. _________ Join the support voice conference net by dialing (619) 939-6338 (SIMLAB operator wll make the first call).
5. _________ Conduct communication check with all participants.
6. _________ Boot all equipment.
7. _________ Verify equipment connections (Ethernet, keyboard, mouse).
8. _________ Verify NTP is running and synchronized to the display clock.
9. _________ Start NETLOOK and verify operation.
10. _________ Verify all machines are up.
11. _________ Verify that the DIS logger at each site is up and ready to receive PDUs.
12. _________ Verify that the DIS logger at each site isset to port 6996 and the exercise ID is 0.
13. _________ Direct the SIMLAB to replay a log file for remote machines to use for system checks.
14. _________ Verify each site is receiving the log file.
15. _________ Verify network traffic with each site.
16. _________ Direct SIMLAB to stop playback.
17. _________ Verify with each site that all log files have been created and are empty. The format is: `mmddyy_test#_lab.lgr (ls -al /disk2/stricom/log/)`

LINKED SIMULATORS PHASE

NETWORK COORDINATOR CHECKLIST

FOR EACH TEST RUN

Network Coordinator: ______________________

Date: ______________ Lab Time: _______ to ________

1. Use data sheets with filenames.
2. When told by the Test Controller, direct all operators to start recording data ("Recorders ON").
3. Test run. Record data.
4. When told by the Test Controller, direct all operators to stop recording data ("Recorders OFF").
5. Direct all operators to close test file.
6. Confirm that each site has logged required data in the written log.
7. Direct all SNAP operators to open the next logger file.

During break

7. Direct operators to run system checks, if necessary.
8. Direct operators to run ping tests, if necessary.
9. Direct operators to run latency tests, if necessary.
10. Direct operators to run time synchronization tests, if necessary.
11. Direct SNAP operators to compress their data.
12. Direct F-14 WSIC to change VCR tapes.
13. Report completion and results to the Test Controller.

LINKED SIMULATORS PHASE

NETWORK COORDINATOR CHECKLIST

END OF DAY

Network Coordinator: ______________________

Date: _______________ Lab Time: ________ to ________

In the spaces provided, record the time each action is completed.

1. _________ Ensure data is in the proper directory with the correct file name. Include: logger files, SNAP files, ping files, time synch files, and system check files. Format for directory is: `disk2/data/mmddyy/machine_name/`

2. _________ RCP F-14 WSIC files to the BMIC.

3. _________ Ensure F-18 WSSF files are at the SIMLAB.

4. _________ RCP SIMLAB files to the BMIC.

5. _________ Backup data to tape using the ***tar -cvf*** command (or tape tool).

6. _________ Verify backup using the***tar -tf*** command (or tape tool).

7. _________ Label the tape.

8. _________ Compress the files on disk in the `/disk2/data/mmddyy/machine_name/` directory.

9. _________ Leave support voice conference net.

10. _________ Turn off all equipment.

11. _________ Participate in mission debrief.

LINKED SIMULATORS PHASE

SITE SUPERVISOR CHECKLIST

DAY BEFORE TEST

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Supervisor: ______________________

Date: ______________ Lab Time: ________ to _________

In the spaces provided, record the time each action is completed.

1. _________ Join the command voice conference net by dialing (619) 939-0010 (SIMLAB supervisor will make the first call)

2. _________ Receive reports from the SNAP and DIS logger operators at your site concerning the status of their equipment.

3. _________ Report site status to the Test Controller.

4. _________ F-14 WSIC and F-18 WSSF Site Supervisors leave voice conference net. SIMLAB Site Supervisor end voice conference net when all other participants have signed off.

5. _________ Brief mission.
   - A. ________ Discuss equipment readiness and any repairs required.
   - B. ________ Establish arrival times of key personnel.
   - C. ________ Review mission procedures and test cards.
   - D. ________ Ensure that your logger operators have enough supplies for the entire test period on hand (checklists, file lists, blank hardware/software discrepancy log sheets, pens or pencils, scratch paper, 4mm tape cartridges, crypto keys, safe combinations).

6. _________ Coordinate repairs as necessary to prepare equipment for the next day (T-23hrs. to T-60 min.).

LINKED SIMULATORS PHASE

SITE SUPERVISOR CHECKLIST

DAY OF TEST BEFORE TEST RUNS

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Supervisor: ______________________

Date: ______________ Lab Time: ________ to ________

In the spaces provided, record the time each action is completed.

1. ________ Join the command voice conference net by dialing (619) 939-0010 (SIMLAB supervisor will make the first call).

2. ________ Ensure logger operators have the applicable checklists, blank log sheets, file lists, pens or pencils, scratch paper and backup media).

3. ________ Receive reports from the SNAP and STRICOM logger operators at your site concerning the status of their equipment.

4. ________ Verify with the laboratory supervisor that the simulation is fully functional.
   Cockpit switchology (Card A) (WSSF)
   INS/GPS/SAHRS/TMS (WSIC)
   Gas bottles (SIMLAB)

5. ________ Label all removable storage media.

6. ________ Report site status to the Test Controller.

LINKED SIMULATORS PHASE

SITE SUPERVISOR CHECKLIST

FOR EACH TEST RUN

Site: (circle one) F-14 WSIC   F-18 WSSF   SIMLAB

Supervisor: ______________________

Date: _______________   Lab Time: ________ to ________

1. Ensure simulation recorders are running.
2. Report site ready for next run.
3. When directed by the Test Controller direct simulation operators to start simulations.
4. F-18 WSSF back up pilot on "Fox" call.
5. F-18 WSSF record data from display for quick look. Report completion to Test Controller.
6. SIMLAB verify shot box not exceeded.

LINKED SIMULATORS PHASE

SITE SUPERVISOR CHECKLIST

END OF DAY

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Supervisor: ______________________

Date: _______________ Lab Time: ________ to _________

In the spaces provided, record the time each action is completed.

1. _________ Gather checklists, logs, notes and removable storage media.
2. _________ SIMLAB print log file.
3. _________ Recheck labeling on logs and removable media.
4. _________ Conduct site debrief.
5. _________ Leave voice conference net.
6. _________ Participate in mission debrief with all sites.

LINKED SIMULATORS PHASE

SNAP OPERATOR CHECKLIST

DAY BEFORE TEST

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Operator: ________________________

Date: ________________ Lab Time: ________ to _________

In the spaces provided, record the time each action is completed.

1. _________ Ensure enough supplies for the entire test period are on hand (checklist, blank hardware/software discrepancy log sheets, file list, pens or pencils, scratch paper, 4mm tape cartridges).
2. _________ Verify equipment connections (Ethernet #1, Ethernet #2, IRIG-B, keyboard, mouse). (Cannot be done at the WSSF)
3. _________ Join the support voice conference net by dialing (619) 939-6338 (SIMLAB operator will make the first call).
4. _________ Start SNAP computer per the attached procedures.
5. _________ Set SNAP to filter on appropriate PDU and Ethernet data.
6. _________ Test SNAP operation by observing pings sent by the DIS logger operator at your site. (Cannot be done at the WSSF)
7. _________ Report to the Network Coordinator when you are ready to conduct the data collection test.
8. _________ When directed by the Network Coordinator conduct a data collection test by receiving specified data.(Cannot be done at the WSSF)
9. _________ Report the results of system checks to your Site Supervisor and the Network Coordinator.
10. _________ Leave the voice conference net.
11. _________ Attend mission brief.
12. _________ Make repairs as necessary (T-23 hrs. to T-60 min.).

LINKED SIMULATORS PHASE

SNAP OPERATOR CHECKLIST

DAY OF TEST BEFORE TEST RUNS

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Operator: ______________________

Date: ______________ Lab Time: ________ to ________

In the spaces provided, record the time each action is completed.

1. ________ Arrive on site.

2. ________ Open written log.

3. ________ Ensure enough suppliesfor the entire test period are on hand (checklist, blank hardware/software discrepancy log sheets, file list, pens or pencils, scratch paper, 4mm tape cartridge).

4. ________ Verify equipment connections (Ethernet #1, Ethernet #2, IRIG-B, keyboard, mouse).

5. ________ Join the support voice conference net by dialing (619) 939-6338 (SIMLAB operator will make the first call).

6. ________ Start SNAP computer per the attached procedures.

7. ________ Set SNAP to filter on appropriate PDU and Ethernet data.

8. ________ Test SNAP operation by observing pings sent by the DIS Logger operator at your site.

9. ________ Report to the Network Coordinator when you are ready to conduct the data collection test.

10. ________ When directed by the Network Coordinator, conduct a data collection test by sending and receiving specified data.

11. ________ Report the results of system checks to your Site Supervisor and the Network Coordinator.

12. ________ Run "***(DATE)files.bat***" to create files. Verify all files have been created and are empty.

LINKED SIMULATORS PHASE

SNAP OPERATOR CHECKLIST

FOR EACH TEST RUN

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Operator: ________________________

Date: ________________ Lab Time: ________ to _________

1. Start recording when directed by the Network Coordinator. Record PDUs and Ethernet packets from all installed Ethernet cards. Verify that PDUs and Ethernet packets are on the network.

2. Stop recording when directed by the Network Coordinator, NOT BEFORE.

3. Save data to file.

4. Check file name off run sheet.

5. Report to your Site Supervisor and the Network Coordinator when you are ready for the next run.

During break

6. Compress files.

7. Report completion to your Site Supervisor and to the Network Coordinator.

LINKED SIMULATORS PHASE

SNAP OPERATOR CHECKLIST

END OF DAY

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Operator: ______________________

Date: ______________ Lab Time: ________ to ________

In the spaces provided, record the time each action is completed.

1. ________ Ensure the data is in the proper directory (`c:/SNAP`) with the proper filename.
2. ________ Reboot SNAP into Windows 95 mode.
3. ________ Backup data files into a zip file using ***WIN Zip***.
4. ________ F-14 WSIC and F-18 WSSF RCP files to the BMIC and SIMLAB respectively.
5. ________ Quit Windows 95 and shut down computer.
6. ________ Leave voice conference net.
7. ________ Give all checklists, written logs, notes, file lists and removable media to your Site Supervisor.
8. ________ Attend mission debrief.

LINKED SIMULATORS PHASE

SNAP OPERATOR CHECKLIST

SNAP START-UP PROCEDURES

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Operator: ____________________

Date: ______________ Lab Time: _______ to ________

1. Turn on power
   A. Wait for the system to boot to the startup menu
   B. Select option 2 from the menu
   C. Press Alt-SysReq
   D. Login -- ***snap***
   E. Password -- ***snap***
   F. ***snap***
   G. Press Alt-SysReq
   H. Type ***cd snap***
   I. Press Alt-SysReq
   J. Type ***snap***

2. `Initial Setup`
   A. Choose `FILE` from menu, then `LOAD CONFIGURATION`
   B. Select appropriate configuration file
   C. Click on `RETURN`

3. `Configure`
   A. Confirm GPS is set to YES
   B. Select `ETHERNET #1` (F-14 WSIC) or `BOTH` (F-18 WSSF and SIMLAB)
   C. Click `SAVE I/O SCHEDULE`

4. I/O Setup
   A. Ethernet #1 receive setup
      1. `BROADCAST`
      2. Set for data to collect (`PDU Headers Only`)
      3. Click `SAVE ETHERNET SETUP`
   B. Ethernet #2 receive setup
      1. `PROMISCUOUS`
      2. Set for data to collect (`ETHERNET HEADERS` and `VARIABLE DATA`: 150 bytes).
      3. Click `SAVE ETHERNET SETUP`
   C. Click on `RETURN`

LINKED SIMULATORS PHASE

SNAP OPERATOR CHECKLIST

5. OPERATE
   A. DISPLAY MODE
   B. Enter screen for PDU GRAPH (display Ethernet #1 OR #2) or Statistics (display Ethernet #1 AND #2)
   C. Press START to record and view
   D. Press STOP to stop recording
   E. Press SAVE DATA
   F. Give file the next name from the file list

* Repeat steps 5A through 5F for each run

TO COMPRESS FILES

1. Click on QUIT from SNAP main screen
2. Press RESET Button
3. Enter Windows 95 (menu option #1)
4. Type ***snap*** at password screen
5. Go into Windows Explorer
   -- Data files are stored in c:/snap
6. Highlight the files to be zipped
7. On highlighted files, click right mouse button
8. Choose ADD TO ZIP
9. Choose I AGREE
10. Enter file name (name.zip)
11. Exit Windows 95 to SNAP
    A. Go to START (bottom of screen tool bar, lights up when mouse arrow points to area)
    B. Choose SHUT DOWN
    C. Choose RESTART COMPUTER
12. Return to step 1A on previous page to record more data.

TO FTP ZIP FILES TO DIS LOGGER COMPUTER FOR SAVING AND TAPING

1. Choose WinFTP in Windows 95, then CONNECT (at bottom of screen)
2. Type in destination computer name (IP#) and host ID (ie *tcac_indy*)
3. For your ID type ***dislog***
4. Type in password (same password as used to enter the DIS logger)
5. Choose OK
6. When you have verified the connection, choose disk2 in remote computer files screen
   A. choose the file name corresponding to your location
   B. open this file
7. Highlight the .ZIP file to be transferred

LINKED SIMULATORS PHASE

SNAP OPERATOR CHECKLIST

8. Click on the right arrow button in the center between the directories
9. Verify that the files have been transferred

TO SET UP PRE-LABELED FILES IN SNAP BEFORE THE TEST

1. Run batch file, "***(date)files.bat***", from `c:/snap directory` (60 blank files will be created)
2. This will create "Required Parameter Missing" errors; IGNORE THESE MESSAGES
3. To edit and change date
   A. Type ***edit (date)files.bat***
   B. Press **Alt S** (for search menu)
   C. Select `CHANGE`
   D. Change data from 0801r to 0805r, or other appropriate date
   E. Select `CHANGE ALL`
   F. Select `FILE` then `SAVE` to save these changes
   G. Select `FILE` then `EXIT` to exit back to `c:/snap`

LINKED SIMULATORS PHASE

DIS LOGGER OPERATOR CHECKLIST

DAY BEFORE TEST

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB BMIC/TCAC

Operator: ______________________

Date: ______________ Lab Time: ________ to ________

In the spaces provided, record the time each action is completed.

1. ________ Ensure enough supplies for the entire test period are on hand (checklist, blank hardware/software discrepancy log sheets, pens or pencils, scratch paper, 4mm tape cartridges).

2. ________ Join the support voice conference net by dialing (619) 939-6338 (SIMLAB operator will make the first call).

3. ________ Boot all equipment.

4. ________ Turn off screen savers.

5. ________ Start STRICOM logger.

6. ________ Open `test_setup` file (create, if necessary). Change port number to 6996 and exercise ID to 0, then apply the changes.

7. ________ Verify all log files have been created and are empty. The format is: `mmddyy_test#_lab.lgr (ls -al /disk2/stricom/log/)`

8. ________ Coordinate with the SNAP operator at your site to test SNAP. (Cannot be done at the WSSF)

9. ________ Conduct system test. Select ***"system test"*** from the menu in the upper left corner of your screen. Verify the data in `/disk2/system/system_check.log`

10. ________ Conduct time synchronization test. Select ***"time synch test"*** from the menu in the upper left corner of your screen. Record and report to the Network Coordinator time differences of 0.5 milliseconds or greater.(Cannot be done at the WSSF)

11. ________ Conduct ping test. Select ***"ping test"*** from the menu in the upper left corner of your screen. Verify data in `/disk2/ping/ping_test.log` file. (Cannot be done at the WSSF)

LINKED SIMULATORS PHASE

DIS LOGGER OPERATOR CHECKLIST

12.________ Report to the Network Coordinator when you are ready to conduct the data collection test.

13.________ When directed by the Network Coordinator, conduct a data collection test by sending and receiving specified data. The SIMLAB operator will send a log file for the SNAP and other DIS logger operators to receive.

14.________ Verify logger sees DIS entities by using the ***"statistics"*** push button.

15.________ Record `test_setup` logger file.

16.________ Stop logger at the end of the test.

17.________ Run "***count_pdus***" (using `test_setup.lgr` as input file). Report problems to the Network Coordinator.

18.________ Report the results of system checks to your Site Supervisor and the Network Coordinator.

19.________ Leave the voice conference net.

20.________ Attend mission brief.

21.________ Make repairs as necessary (T-23 hrs. to T-60 min.).

LINKED SIMULATORS PHASE

DIS LOGGER OPERATOR CHECKLIST

DAY OF TEST BEFORE TEST RUNS

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Operator: ______________________

Date: ______________ Lab Time: _______ to ________

In the spaces provided, record the time each action is completed.

1. _________ Arrive on site.

2. _________ Open written log.

3. _________ Ensure enough supplies for the entire test period are on hand (checklist, blank hardware/software discrepancy log sheets, pensorpencils, scratch paper, 4mm tape cartridges).

4. _________ Join the support voice conference net by dialing (619) 939-6338 (SIMLAB operator will make the first call).

5. _________ Boot all equipment.

6. _________ Turn off screen savers.

7. _________ Start STRICOM logger.

8. _________ Open `test_setup` file (create, if necessary). Change port number to 6996 and exercise ID to 0, then apply changes.

9. _________ Verify all log files have been created and are empty. The format is: `mmddyy_test#_lab.lgr (ls -al /disk2/stricom/log/)`

10. _________ Coordinate with the SNAP operator at your site to test SNAP.

11. _________ Conduct System Test. Select ***"system test"*** from the menu in the upper left corner of your screen. verify data in `/disk2/system/system_check.log`

12. _________ Conduct time synchronization test. Select ***"time synch test"*** from the menu in the upper left corner of your screen. Record and report time differences of 0.5 milliseconds or greater.

LINKED SIMULATORS PHASE

DIS LOGGER OPERATOR CHECKLIST

13.________ Conduct ping test. Select ***"ping test"*** from the menu in the upper left corner of your screen. Verify data in `/disk2/ping/ping_test.log` file.

14.________ Report to the Network Coordinator when you are ready to conduct the dat a collection test.

15.________ When directed by the Network Coordinator, conduct a data collection test by sending and receiving specified data. The SIMLAB operator will send a log file for the SNAP and other DIS logger operators to receive.

16.________ Verify logger sees DIS entities by using the***"statistics"*** push button.

17.________ Record `test_setup` logger file.

18.________ Stop logger at the end of the test.

19.________ Run "***count_pdus***" (using `test_setup.lgr` as input file). Report problems to the Network Coordinator.

20.________ Report the results of system checks to your Site Supervisor and the Network Coordinator.

22.________ Ensure the first test logger file is open and ready to record.

LINKED SIMULATORS PHASE

DIS LOGGER OPERATOR CHECKLIST

FOR EACH TEST RUN

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Operator: ______________________

Date: ______________ Lab Time: ________ to ________

1. Use data sheets with filenames.

2. Record data when directed by the Network Coordinator.

3. Test run. Record data.

4. Stop recording data when directed by, and NOT BEFORE, the Network Coordinator.

5. Close test file.

6. Report to your Site Supervisor and the Network Coordinator whether data collection was successful.

7. Open the next logger file.

During Break

8. Run system check.

9. Run ping test.

10. Run latency test.

11. F-14 WSIC change VCR tapes.

12. Report completion to your Site Supervisor and the Network Coordinator.

LINKED SIMULATORS PHASE

DIS LOGGER OPERATOR CHECKLIST

END OF DAY

Site: (circle one) F-14 WSIC F-18 WSSF SIMLAB

Operator: ____________________

Date: ______________ Lab Time: ________ to ________

In the spaces provided, record the time each action is completed.

1. ________ Ensure data is in the proper directory with the correct file name. Include: logger files, SNAP files, ping files, time synch files, and system check files. Format for directory is: `/disk2/data/mmddyy/machine_name/` (*e.g.* `/disk2/data/082696/wssf-dislog/`)

2. ________ Backup all logger files to a single tar disk file (`mmddyy_sitename.lgr.tar`) using the ***tar -cvf*** command. Compress the file using the ***compress*** utility.

3. ________ SIMLAB and BMIC backup data to tar tape file using the ***tar -cvf*** command (or tape tool).

4. ________ Verify backup using the ***tar -tf*** command (or tape tool).

5. ________ Compress the disk files in the `/disk2/data/mmddyy/machine_name/` directory.

6. ________ Delete the `.lgr` files.

7. ________ Leave voice conference net.

8. ________ Turn off all equipment.

9. ________ Give all checklists, written logs, notes, 4mmtape cartridge and VCR tapes (if applicable) to the Site Supervisor.

10. ________ Attend mission debrief.

LINKED SIMULATORS PHASE

TEST CARDS

LINKED SIMULATORS PHASE

JADS LSP GENERAL	
MISSION: ________ OPNO: ________	DATE: ________ TIME: ________
WSSF PILOT: ________	**SIMLAB** OPERATOR: ________
WSIC PILOT: ________ RIO: ________	**TCAC** CONTROLLER: ________
WSSF CONFIGURATION F/A-18C / OFP 11C AIM-9M STATION ________	**SIMLAB CONFIGURATION** AIM-9MR (AIM-9M(8/9)) SEEKER SERIAL #: ________
WSIC CONFIGURATION F-14D / OFP D03.2	
NOTES	
	COVER CARD

LINKED SIMULATORS PHASE

F-18 WSSF PROCEDURES

BEFORE FIRST RUN

1. INS - **NAV**
2. RADAR - **OPERATE**
3. SMS POWER - **ON**
4. FLAPS - **AUTO**
5. **PING** EACH REMOTE NODE

BEFORE EACH RUN

1. LOAD NEW MISSILE
   A. ENTER **NAV** MASTER MODE (DESELECT A/A MASTER MODE)
   B. LANDING GEAR POSITION - **DOWN**
   C. LEFT WEIGHT ON WHEELS - **ON**
   D. RIGHT WEIGHT ON WHEELS - **ON**
   E. PARKING BRAKE - **ON**
2. RESET SIMULATION
3. CHECK MNS-1 SMS LINK
4. SELECT **DIRECT CONTROL** AIRFRAME MODEL
   INITIAL CONDITIONS: 12,000' MSL; 450 KTAS; 3.0 AOA
5. INITIALIZE VAX AND HP-735
6. PARKING BRAKE - **OFF**
7. WHEN AIRBORNE
   A. LEFT WEIGHT ON WHEELS - **OFF**
   B. RIGHT WEIGHT ON WHEELS - **OFF**
   C. LANDING GEAR POSITION - **UP**
   D. A/A MASTER MODE SELECT - **ON**
   E. MASTER ARM - **ARM**
8. SIMULATION DATA RECORDING - **START**

CARD A **PAGE 1**

LINKED SIMULATORS PHASE

F-18 WSSF PROCEDURES

TO START EACH RUN

1. SIMULTANEOUSLY SELECT **KOHLMAN** AIRFRAME MODEL AND PROFILE RECORDING - **ON**
2. SMS RECORDER - **ON**

DURING EACH RUN

1. A/A WEAPON SELECT - **SIDEWINDER**
2. SENSOR CONTROL - **AUTO ACQ**
3. CAGE/UNCAGE - **UNCAGE**
4. TRIGGER - PULL TO SECOND DETENT

AFTER EACH RUN

1. SIMULATION DATA RECORDING - **OFF**
2. REPORT QUICK LOOK DATA
3. **SAVE** RECORDED FLIGHT PROFILE FOR PLAYBACK
4. MANUALLY RECORD QUICK LOOK DATA
5. ARCHIVE SAVED FLIGHT PROFILE

CARD A **PAGE 2**

LINKED SIMULATORS PHASE

JADS LSP

INITIALIZE: ______ NM

WSIC (Tgt) - End

WSIC (Tgt) - Start ← WSSF (Shooter)

10.4 KFT / 0.72 imn / 180 deg TAA   11.3 KFT / 0.71 imn / in trail

A. INITIALIZE WSSF, WSIC, AND SIMLAB
B. VERIFY BASELINE SYSTEM SWITCHOLOGY

1. (EACH LAB) "LAB READY"
2. (TCAC) VERIFY WITH NETWORK COORDINATOR THAT THE DATA LOGGERS ARE READY.
3. (TCAC) "PROFILE # ______ ; PASS # ______."
4. (TCAC) DIRECT NETWORK COORDINATOR TO START RECORDERS
5. (TCAC) **NOTE TIME** "RECORDERS ON"
6. (TCAC) NETWORK COORDINATOR REPORTS RECORDERS RUNNING
7. (TCAC) "3-2-1-START RUN"
8. (TCAC) "Step 3"
9. (TCAC) "KNOCK IT OFF"
10. (TCAC) "RECORDERS OFF"
11. (F-18) "DATA CHECK COMPLETE"
12. (SIMLAB) "DATA CHECK COMPLETE"
13. (TCAC) "RESET SIMULATORS"
14. (EACH LAB) "SIMULATORS RESET"
15. (EACH LAB) TO CONTINUE, GO TO STEP 3.

PASS #: ________	**PROFILE #: V1**	

LINKED SIMULATORS PHASE

JADS LSP

INITIALIZE: ______ NM

WSIC (Tgt) - End

WSIC (Tgt) - Start ← WSSF (Shooter)

10.4 KFT / 0.72 imn / 180 deg TAA — 11.3 KFT / 0.71 imn / in trail

A. INITIALIZE WSSF, WSIC, AND SIMLAB
B. VERIFY BASELINE SYSTEM SWITCHOLOGY

1. (EACH LAB) "LAB READY"
2. (TCAC) VERIFY WITH NETWORK COORDINATOR THAT THE DATA LOGGERS ARE READY.
3. (TCAC) "PROFILE # ______ ; PASS # ______."
4. (TCAC) "STEP 1"
5. (SIMLAB) "15 SECONDS TO GO"
6. (TCAC) DIRECT NETWORK COORDINATOR TO START RECORDERS
7. (TCAC) **NOTE TIME** "RECORDERS ON"
8. (TCAC) NETWORK COORDINATOR REPORTS RECORDERS RUNNING
9. (TCAC) "3-2-1-START RUN"
10. (SIMLAB) "STEP 2"
11. (TCAC) "STEP 3"
12. (TCAC) "KNOCK IT OFF"
13. (TCAC) **NOTE TIME** "RECORDERS OFF"
14. (F-18) "DATA CHECK COMPLETE"
15. (SIMLAB) "DATA CHECK COMPLETE"
16. (TCAC) "RESET SIMULATORS"
17. (EACH LAB) "SIMULATORS RESET"
18. (EACH LAB) TO CONTINUE, GO TO STEP 3.

PASS #: ________	PROFILE #: V2	

LINKED SIMULATORS PHASE

TEST CONTROLLER LOG

Run No.	Profile	Run Start Time	Run Stop Time	Abort? (Y/N)	Remarks (Abort Reason, Trial Problems, Observations)

MISSION: ____________ **DATE:** ____________

LINKED SIMULATORS PHASE

SIMLAB QUICK-LOOK DATA FORM

Run No.	Profile	All Parameters in Shot Box? (Y/N/Exceptions)	Remarks

MISSION: ___________ **DATE:** ___________

LINKED SIMULATORS PHASE

LINKED SIMULATORS PHASE

F/A-18 QUICK-LOOK DATA

Run No.		Profile		Run No.		Profile		Run No.		Profile	
Range		Altitude		Range		Altitude		Range		Altitude	
Vc		TAS		Vc		TAS		Vc		TAS	
V		FPA		V		FPA		V		FPA	
Δ Altitude		Roll Rate		Δ Altitude		Roll Rate		Δ Altitude		Roll Rate	
Aspect				Aspect				Aspect			

Run No.		Profile		Run No.		Profile		Run No.		Profile	
Range		Altitude		Range		Altitude		Range		Altitude	
Vc		TAS		Vc		TAS		Vc		TAS	
V		FPA		V		FPA		V		FPA	
Δ Altitude		Roll Rate		Δ Altitude		Roll Rate		Δ Altitude		Roll Rate	
Aspect				Aspect				Aspect			

Run No.		Profile		Run No.		Profile		Run No.		Profile	
Range		Altitude		Range		Altitude		Range		Altitude	
Vc		TAS		Vc		TAS		Vc		TAS	
V		FPA		V		FPA		V		FPA	
Δ Altitude		Roll Rate		Δ Altitude		Roll Rate		Δ Altitude		Roll Rate	
Aspect				Aspect				Aspect			

LINKED SIMULATORS PHASE

MISSION: ____________ **DATE:** ____________

LINKED SIMULATORS PHASE

NETWORK COORDINATOR LOG

Run No.	Profile	F/A-18 Sim Data Recorded (Y/N)	F/A-18 DIS Loggers Recorded (Y/N)	F/A-18 SNAP Loggers Recorded (Y/N)	F-14 Sim Data Recorded (Y/N)	F-14 DIS Loggers Recorded (Y/N)	F-14 SNAP Loggers Recorded (Y/N)	SIMLAB Sim Data Recorded (Y/N)	SIMLAB DIS Loggers Recorded (Y/N)	SIMLAB SNAP Loggers Recorded (Y/N)	BMIC DIS Loggers Recorded (Y/N)	Remarks

MISSION: ____________ **DATE:** ____________

LINKED SIMULATORS PHASE

LINKED SIMULATORS PHASE

SITE SUPERVISOR

HARDWARE/SOFTWARE FAILURE LOG

Date	Profile	Pass No.	Machine Name	Program/ Device Name	Failure Type (H/W or S/W)	Time of Failure	Time Repair Complete	Time Up

APPENDIX F

ACRONYM LIST

for the

SYSTEM INTEGRATION TEST

LINKED SIMULATORS PHASE

ACRONYM LIST

6-DOF	Six (6) Degree-of-Freedom
ADI	Applied Dynamics International
ADS	Advanced Distributed Simulation
AMRAAM	Advanced Medium Range Air-to-Air Missile
ARPA	Advanced Research Projects Agency
BMIC	Battle Management Interoperability Center
C4I	Command, Control, Communications, Computers, and Intelligence
CCM	Counter-Countermeasures
CCR	Captive Carry Reliability
CM	Countermeasures
COI	Critical Operational Issue
COMSEC	Communications Security
CPU	Central Processor Unit
CSU	Channel Service Unit
DEC	Digital Equipment Corporation
DIS	Distributed Interactive Simulation
DDT&E	Deputy Director, Test, Systems Engineering and Evaluation (Test and Evaluation)
DMAP	Data Management and Analysis Plan
DMSO	Defense Modeling and Simulation Organization
DSI	Defense Simulations Internet
DSU	Data Service Unit
DT	Developmental Testing
DT&E	Developmental Test and Evaluation
ES	Entity State
ESSM	Evolved Sea Sparrow Missile
ETE	End-to-End Test
GCS	Guidance and Control Section
GMT	Greenwich Mean Time
GPS	Global Positioning System
HUD	Heads-Up Display
H/W	Hardware
HWIL	Hardware-in-the-Loop
ICD	Interface Control Document
IR	Infrared

IRCM	Infrared Countermeasures
IRCCM	Infrared Counter-Countermeasures
IRIG	Interrange Instrumentation Group
ITP	Integration Test Plan
JADS	Joint Advanced Distributed Simulation
JDAM	Joint Direct Attack Munition
JIOT&E	Joint Initial OT&E
JORD	Joint Operational Requirements Document
JSPO	Joint System Program Office
JT&E	JADS Joint Test and Evaluation
JTD	Joint Test Director
JTF	JADS Joint Test Force
LAN	Local Area Network
LFP	Live Fly Phase
LOS	Line-of-Sight
LSP	Linked Simulators Phase
LTE	Launch-to-Eject
LTP	Laboratory Test Plan
MCMTOMF	Mean Corrective Maintenance Time for Operational Mission Failures
MNS-1	MIL-STD-1553 Networking System
MOA	Memorandum of Agreement
MTBOMF	Mean Time Between Operational Mission Failures
MWS	Missile Warning System
NAWCWPNS	Naval Air Warfare Center Weapons Division
NIU	Network Interface Unit
NRNet	NAWCWPNS Real-Time Network
OAR	Open Air Range
OD	Operations Directive
OFP	Operational Flight Program
OFS	Operational Flight Software
OPSEC	Operations Security
OR	Operation Requirements
OSD	Office of the Secretary of Defense
OT	Operational Testing
OT&E	Operational Test and Evaluation
PDU	Protocol Data Unit
PI	Program Introduction
PTP	Program Test Plan

RAM	Reliability, Availability, Maintainability
RDT&E	Research, Development, Test, and Evaluation
RSS	Root-Sum-Square
RT	Remote Terminal
SA	Subaddress
SGI	Silicon Graphics, Inc.
SIMLAB	Sidewinder Simulation Laboratory
SIT	System Integration Test
SIU	Simulation Interface Unit
SMS	Stores Management System
SNAP	Simulator Network Analysis Project
SNMP	Simple Network Management Protocol
SOC	Statement of Capability
SSC	Simulation Specific Component
STRICOM	Simulation, Training, and Instrumentation Command
SUT	System-Under-Test
S/W	Software
T&E	Test and Evaluation
TAP	Test Activity Plan
TCAC	Test Control and Analysis Center
TCP/IP	Transmission Control Protocol/Internet Protocol
TEMP	Test and Evaluation Master Plan
TFR	Test Facilities and Resources
TM	Telemetry
TOF	Time of Flight
TSPI	Time-Space-Position Information
UDS	Universal Documentation System
UDX	Universal Data Exchange
UTC	Universal Time Code
V&V	Verification and Validation
VTC	Video Teleconference
VV&A	Verification, Validation, and Accreditation
WAN	Wide Area Network
WRAs	Weapon Replacement Assemblies
WSIC	Weapons System Integration Center
WSSF	Weapon System Support Facility